Theses and Dissertations   1. Thesis and Dissertation Collection, all items

1982

A systems approach to contingency modelling

Riddle, Thomas H.; Snyder, Thomas L.

Monterey, California. Naval Postgraduate School

http://hdl.handle.net/10945/20368

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

A SYSTEMS APPROACH TO CONTINGENCY MODELLING

by

Thomas H. Riddle
and
Thomas L. Snyder

October 1982

Thesis Advisors: J. K. Hartman and S. H. Parry

T205759

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A Systems Approach to Contingency Modelling		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis October 1982
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Thomas H. Riddle and Thomas L. Snyder		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE October 1982
		13. NUMBER OF PAGES 97 pages
14. MONITORING AGENCY NAME & ADDRESS(If different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Contingency modelling, deployment modelling, mobilization modelling.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This thesis presents an architecture to be used in an automated methodology for the validation of operations plans (OPLANS). The approach uses high resolution stochastic and deterministic simulation to model the activities of implementing a contingency plan. Operations are divided into three distinct major areas; Mobilization, Deployment, and Employment. Each of these major areas is modelled by a series of modules which depicts the activities and

DD FORM 1473 EDITION OF 1 NOV 65 IS OBSOLETE
1 JAN 73
S/N 0102-014-6601 |

Item 20 (contd):

processes which take place during the operation. The use of this
approach for analysis of contingency plans provides the capability
for updating and reevaluation of Joint OPLANS.

A Systems Approach to Contingency Modelling

by

Thomas H. Riddle
Captain, United States Army
B.S., West Virginia University, 1977

and

Thomas L. Snyder
Captain, United States Army
B.S., United States Military Academy, 1974

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
October 1982

ABSTRACT

This thesis presents an architecture to be used in an automated methodology for the validation of operations plans (OPLANS). The approach uses high resolution stochastic and deterministic simulation to model the activities of implementing a contingency plan. Operations are divided into three distinct major areas; Mobilization, Deployment, and Employment. Each of these major areas is modelled by a series of modules which depicts the activities and processes which take place during the operation. The use of this approach for analysis of contingency plans provides the capability for updating and reevaluation of joint OPLANS.

TABLE OF CONTENTS

LIST OF FIGURES

I.   INTRODUCTION

A.   PROBLEM STATEMENT

The United States Readiness Command (REDCOM) is a joint command tasked with the responsibility to plan, coordinate, and evaluate U.S. planning to meet military contingencies. A large number of diverse organizations including the services and various agencies work under guidance from REDCOM attempting to solve this complex problem. Each of these organizations in the joint arena has its own priorities, perceptions and viewpoints which magnify the difficulty of trying to solve the problem. Evaluation of contingency plans, a major REDCOM responsibility, is virtually impossible short of an extremely large and expensive Command Post Exercise (CPX) or the actual outbreak of war. Lessons learned from the former are often obscured by the lack of control in data collection and the occurrence of the latter is too late.

There is a perceived need for an automated methodology to validate contingency plans. Design of an architecture for such an automated system requires compatibility among the models and methods employed by each of the participating agencies. Interdependencies of models utilized to represent small segments of the problem require an audit trail of events, activities, and resources throughout the system.

This audit trail should provide the capability for central-
ized sensitivity analysis and evaluation of the system.

B. PROCEDURE

The first step in solving any large, complex problem is
to define it and then break it into manageable pieces for in-
vestigation. In this instance, the initial step consists of
separating the contingency (real world) from a model of the
contingency and analyzing it.

The military operation consists of all those processes
which exchange information, evaluate reports and information,
make decisions and implement directives. A contingency
implies that a military operation will take place in
response to some set of circumstances which make up the con-
tingency. This military operation is partitioned in three
major areas; mobilization, deployment, and employment. In
this thesis, mobilization and deployment will be examined
and employment investigated only to the extent that it
affects the other two. These areas are divided into minor
areas of sea and air in order to make the analysis more
easily handled.

To unerringly model each of the processes which takes
place in these partitions is beyond the scope of technology.
Even if feasible, faithful representation of each process
would require a tremendously large amount of date and time.
The process of modelling the operation first requires

11

identification of the most important "real world" processes
and design of models and modules to correspond to these
major and minor areas in the contingency.

Mobilization and Deployment models represent the corres-
ponding major areas of the real world. Each of these models
is in turn comprised of modules which model the activities
of that area. These modules represent the marshalling of
air/sea resources, assignment of missions, implementation
of mission instructions and iterative repetition of the cycle
until the operation is concluded.

This thesis examines the input and output flows between
each of the models and their modules. Appropriate methodolo-
gies for modelling the processes in each of the areas are
examined and recommendations for their use are made. A
careful study of each of the models is conducted to determine
the appropriate degree of dependence between modules and
models in order that it not be necessary to operate the
entire system simultaneously. An objective is the capability
to reduce the dependence between models to the point that
only access to filed information from models is required,
thus allowing independent running of the components rather
than continuous real time interaction between models.

The ultimate objective of this thesis is the design of
an architecture for the analysis of contingency plans in a
coordinated manner. This architecture should provide the

National Command Authority (NCA) the capability to conduct automated validation of Operations Plans (OPLANS) with relatively short response time and no loss of information as is frequently the case in a CPX. As a result the NCA should be able to conduct sensitivity analysis at a very centralized level.

II.   ANALYSIS OF THE REAL WORLD

A.   PARTITIONING THE REAL WORLD INTO FUNCTIONAL AREAS

In order to study a process as complex as a military operation being conducted over long lines of communication and resupply, it is necessary to divide the process into segments. This process also helps the modeler in that it partitions his work. The modeler then constructs the pieces and appropriately ties them together. In this case the process of breaking these areas down is iterative. The overall military operation is first broken into large pieces which will be referred to as major areas. These major areas are each partitioned into smaller portions called minor areas. In some cases this is far enough; however, in other areas it is necessary to further split the minor areas into sub-areas. In the future as deeper treatments of the subject are developed, even finer levels of partitioning will be necessary.

The division of the overall military operation into functional areas provides a structure for the study of the operation and the construction of an appropriate model of these functions. The subarea functions will be modeled by modules that interrelate to form the models of the minor area functions called sections. The major areas will be free-standing models with interrelating input/output.

14

B.   MAJOR AREAS

The overall process of responding to a major military contingency outside of CONUS is split into three major areas. These areas are (1) mobilization of transportation assets, (2) deployment of troops, equipment, logistics, and re-supplies to the theather of operations via these assets, and (3) the actual employment or combat of these forces.

1.   Mobilization of Transportation Assets (Mobilization)

This area consists of modelling the location and in certain circumstances the return of transportation assets to CONUS from their peacetime missions. This section of the real world is designated a major area because of the relatively little impact the other areas have on this area. The converse is not true.

2.   Deployment of Forces (Deployment)

This partitioning of the real world is concerned with the transportation of all cargo and personnel to the theater of operations. It is designated a major area because of the many feedback channels in this area. This makes the close and constant communication of the subareas in this area essential. This area is divided into two minor areas by type of transport. The two areas are sea and air.

3.   Employment of Forces (Employment)

This area is partitioned because there exist many theater combat models that with some modification could

represent this area of the real world. For this reason discussion of Employment in this thesis is limited to those aspects that affect the other two major areas.

C. FUNCTIONAL SUBAREAS DESCRIPTION

This section will discuss the subareas of the mobilization and deployment major areas. They are air/sea mobilization/deployment. This division is convenient because of the logical breakdown of these two means of transportation to theaters of operation. This breakdown is depicted in Fig. 1, Partitioning of the Real World.

1. Sea

There are eight basic subareas that form the building blocks of the sea minor area in the major areas of mobilization and deployment. These subareas are discussed in detail in the following sections but a brief description of each is provided here.

a. The ship mobilization (S MOB) subarea is the transition from a peacetime utilization of sea lift assets to a crisis or wartime utilization. Ships move to various locations based upon peacetime missions and in an emergency return to CONUS. The return of each ship is based upon the mobilization classification of the ship and when that classification is ordered mobilized. Along the way it is possible that the ship will be attacked by the enemy or delayed by RAM failures.

16
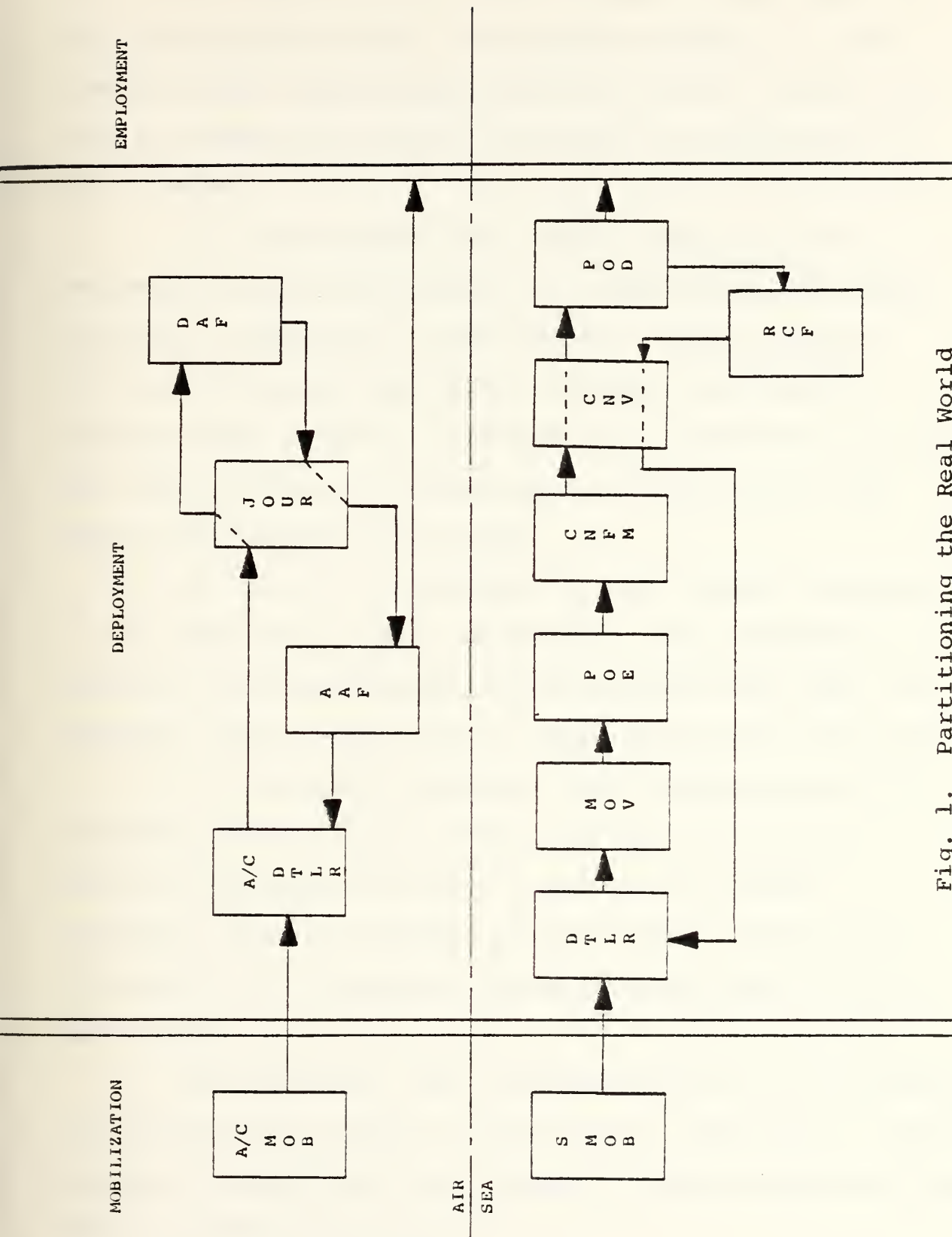
Fig. 1. Partitioning the Real World

17

b. The detailer (S DTLR) subarea is the brain of the sea deployment area. It decides what ships to send where and what cargo these ships will pick up. This is the area of command and control functions in the Military Sea Lift Command.

c. The movement (MOV) subarea consists of the movement of ships individually or in small groups in close proximity to the ports of embarkation. After the ship mobilization subarea mobilizes the ship, and detailer decides where to send it, movement is the function of sailing the ship to its port of embarkation. Along the way the enemy could interdict the ships.

d. The port of embarkation (POE) subarea consists of the activities at the loading port. This includes the actions of actually loading and provisioning the ship, any necessary repair work, and the queue waiting for dock space.

e. The convoy formation (CNFM) subarea plans and organizes convoys, which consist of one or more ships. Based on the enemy situation, loaded ships waiting, pressing need in the theater of operations, and the available escorts, this subarea decides when and where to form up convoys.

f. The convoy (CNV) subarea consists of the movement of convoys to the theater of operations. Ships move, consume fuel, are refueled and are involved in combat operations upon enemy interdiction attempts.

g. The port of debarkation (POD) subarea consists of the actions at the unloading port. This is very similar to the port of embarkation except the assembling and reconstituting of units separated during transit must also take place.

h. The return convoy formation (RCF) plans return convoys in much the same way that convoy formation plans outgoing convoys.

There are five basic subareas that form the basic building blocks of the air minor area in the mobilization and deployment major areas. The subareas are discussed in detail in the following sections but a brief description is provided here.

1. The aircraft mobilization (A/C MOB) subarea is similar to the ship mobilization subarea. It consists of the process of keeping track of the aircraft's location while on peacetime missions. Then the detailer and journey subareas move the aircraft back to CONUS.

2. Aircraft detailer (A/C DTLR) is the subarea that consists of the decision/command and control process. It picks up aircraft at their initial location from the aircraft mobilization subarea or at the finish of their previous mission from the arrival airfield subarea and assigns them a new mission. In doing this it takes into account characteristics of the cargo, arrival and departure airfields, and the aircraft.

19

3. The journey (JOUR) subarea consists of the flight of the aircraft from point A to point B. Based on the distance and the enemy situation between the two points, the aircraft is refueled and possibly attacked by enemy anti-air assets.

4. Departure airfield (DAF) is the subarea that is made up of all the relevant activities at the loading airfield. This includes cargo preparation, handling, and aircraft maintenance.

5. The arrival airfield (AAF) subarea contains the functions of the arrival airfield in the theater of operations. This includes all activities which unload the aircraft and perform maintenance and refueling operations. It also includes enemy attacks against aircraft at the airfield.

2. Subareas of Sea Mobilization and Deployment

a. Ship Mobilization (S MOB)

This subarea consists of the processes that transition the civilian and military seaborne assets from peacetime to wartime utilization. For every ship this consists of three basic processes. The first process is that of the ship going about its peacetime mission. The second process is that of the command and control procedures that decide to mobilize the ship and commit it to the support of the military operation in question. The return of the

20

ship from its initial location to the CONUS or to designated forward basis is the third process.

There are three relevant issues to military study of the ship's peacetime activities.

(1) The issue of where these activities cause the ship to be located when it is authorized for use in the military operation is the first.

(2) The second issue is what peacetime commitments of the ship should be fulfilled prior to requiring its return to CONUS or forward basing areas and under control of the National Command Authority.

(3) The issue of what modifications will need to be made to the ship for utilization as a military carrier but can't be made while the ship is fulfilling its peacetime mission is the third.

The procedures of command and control of the seaborne transportation mobilization consist of the processes of designating military cargo ships to support the military operation and the process of calling into service the civilian shipping assets of the country. This process is time phased and dependent upon the urgency in the theater of operations.

The process of returning the ship to the CONUS area is one that involves all the processes of sailing the ship. These include movement, consumption of provisions,

and possible conflict with enemy forces if the enemy has the capability to interdict the ship's route of return.

      b.   Detailer (S DTLR)

The detailer subarea is concerned with the command and control processes that assign missions to the various ships. The interesting issues are: "What form do the missions take?" and "What is the basis for the decision?"

The missions consist of where to go, what to carry, and when should the mission be executed. The ship's mission assigns the ship to one or more ports of embarkation where the ship picks up cargo. The mission specifies what this cargo will be and assigns the ship to one or more ports of debarkation where it offloads cargo.

The basis for the decisions made by DTLR has many elements. These elements are in conflict. On one hand each ship wants to carry as much cargo as possible and leave as soon as possible while the priority of delivery wants to load the ship with one item and sent it on its way in accordance with an imposed set of constraints. These constraints include delivery priorities and sequence, ship's cargo carrying constraints, the ship's constraints coupled with the port's constraints, and the backlog at the ports.

c. Movements (MOV)

The movement subarea consists of those processes that result in the movement of ships in close proximity to the ports. These include the processes of moving, RAM failures and enemy action. The process of movement can best be described as distance along a route and modeled by the formula:

distance = rate x time

The RAM failure processes are concerned with the mechanical breakdown of the ship. The process of enemy action is that of combat. In this subarea ships can be moving singly or in small groups.

d. Port of Embarkation (POE)

The port of embarkation subarea contains those processes that take place at the loading port. There are five processes of immediate interest in this area; they are:

(1) Waiting queue in the harbor for dock space to begin loading.

(2) Preparing the cargo for shipment.

(3) Loading of cargo.

(4) Performance of any required maintenance on the ship.

(5) Command and control process which directs all of these activities.

23

The process of waiting in harbor and the actual loading of cargo is fairly self explanatory. The process of cargo preparation consists of those processes necessary to package and protect the cargo. On some ships the cargo may need to be containerized or some other bulk packaging used. Vehicles may also need special treatment to include cleaning and draining of flammable liquids with high vapor pressures.

The process of ship maintenance consists of many activities. Those of interest are the ones that need special port facilities to be accomplished or that cannot be accomplished while underway. The process of command and control consists basically of scheduling all these activities in some logical way that accomplishes these tasks in a minimum of time while giving priority to the ships with the highest priority cargo.

e. Convoy Formation (CNFM)

The convoy formation subarea consists of the command and control activities that plan and dispatch convoys to the theater of operations. This is a decision process that results in the ships from the ports of embarkation sailing to the rendezvous locations to form large convoys for movement to the theater of operations. In conflict with a less capable enemy, the ships might not convoy. In this case this process would result in the

24

ships being dispatched as soon as they were loaded.

The actual form of the decision would be to give the ships in the port of embarkation a time to sail, a rendezvous location, and a rendezvous time. The basis for this decision is that the convoys are organized as soon as possible to get their cargo to the theater of operations. At the same time there need to be enough ships available to constitute a convoy and enough escort ships available to protect the convoy.

f. Convoy (CNV)

The convoy subarea has within it four processes that are of interest to the military analysis of overseas military operations. Those processes are (1) movement, (2) mechanical failures (RAM), (3) replenishment of supplies, and (4) possible combat with enemy forces attempting to interdict the sea resupply route.

The movement process is similar to that described in the movement subarea. It is a rate multiplied by time process where the rate is set by the slowest ship. The mechanical failures result in slower speeds or no speed. They also could result in the ship being diverted to a repair facility. As a result of the movement of the ship, its fuel is consumed along with other items. The replenishment of those items could occur at an intermediate stop or at sea. Added to this is the sea combat process that could occur

25

between the convoy and the enemy's air, surface or sub-surface combatants.

g. Port of Debarkation (POD)

The port of debarkation subarea has within it processes very similar to the port of embarkation. These processes are waiting queue, unloading the cargo, the process of uploading or preparing the cargo for use and the maintenance of the ships. There are two other processes that did not occur in the port of embarkation subarea. These are the assembling of units that may be widely scattered and the possible combat that could result from an enemy air, sea or ground attack on the port.

The process of assembling the units is very complex in that the troops and the equipment could be scattered across several geographical locations. The various components of each unit must be brought together and given time to prepare their equipment.

If the enemy has the capability to strike at the port facilities, these areas may become high priority targets for any air, sea, or ground assets that he can send against them. Failing that, the transportation networks leading into the ports will become prime targets.

h. Return Convoy Formation (MCF)

This section is much like the convoy formation section in that it organizes convoys returning to the CONUS

area. However, the decision is more complex in that the safety of the cargo is no longer a concern and the danger in a port may exceed that at sea.

  3. Aircraft Mobilization and Deployment

    a. Aircraft Mobilization (A/C MOB)

      This subarea consists of marshalling air assets and conducting the transition from peacetime to a wartime environment. Its purpose is to answer two fundamental questions for the decision maker: "Where is each plane to be used currently located?" and "When will each aircraft be available at a designated location in the United States or a forward air base to perform assigned missions?" Each aircraft goes through three states, the first is peacetime operation prior to mobilization, second is the process by which the aircraft is transferred to military control (if part of the civilian reserve airfleet -CRAF) and receives initial instructions. The third state is the performance of assigned missions during military operations.

      The ability to accurately assess the expected location of designated aircraft at any given time requires that distributions based upon the type of aircraft, its cargo capabilities and usual peacetime utilization be available. Also required is a predetermined list of the CRAF and military assets which are available for planning. Each of these information requirements is an input to the

subarea, or better expressed as data known to the decision maker. In addition, the decision maker possesses knowledge of the scenario as it may affect mobilization. An example of this type of knowledge is an overflight restriction which adversely affects flight.

Output from this subarea consists of information which assists other subareas in making decisions about mission assignment and destinations. The location of each aircraft, its expected departure time and the expected time it will be available at some notional control point are output. This information is relayed to a decision making subarea for action.

b. Aircraft Detailer (A/C DTLR)

This is the most complex of the subareas and can be described as the brain of air deployment. All of the decisions about mission assignment, changes in missions and destinations for aircraft are made here. In this sub-area, the processes of matching needs, requirements, and assets take place. In brief, this subarea's function is to make the best decisions and choose the best alternatives to support the theater of operations. In other words, it maximizes support subject to priorities, aircraft availa-bility, cargo location and other constraints.

The decision making processes are continuous in nature once the operation begins. Once an initial mission

is assigned to an aircraft, it is tracked along its path through to mission completion. Any factors which affect the aircraft's schedule are noted by the DTLR subarea and adjustments made to its expected arrival time. Missions are changed and diversions made in response to changing priorities or new requirements in the theater of operations. DTLR can be compared to a nerve and information center that collates facts relevant to the operation, evaluates their effects and acts upon them accordingly.

c.   Departure Airfield (DAF)

The subarea DAF contains the processes which are activities taking place at an airfield staging area. Events of concern include the actual arrival time of each plane, its state of maintenance and the state of its crew. The crew may be able to take off immediately or may need rest or even replacement prior to departure. The plane itself may require periodic maintenance or major repair work. These factors play major roles in the process of landing and preparing for takeoff. Other processes which need examination are the availability of special tools and equipment to load the cargo and special preparation of vehicles and other equipment for transportation by the planes. Priorities established to meet the needs of the theater commander dictate the establishment of queues for loading and takeoff at each airport. The queueing among aircraft

29

and cargoes is a major potential choke point and is of major interest in successfully minimizing the response time to requirements from the theater of combat.

        d.   Journey (JOUR)

        The processes in this subarea involve flying between a departure point and some destination. The route between any two points is specified and JOUR consists of functions affecting this predetermined flight path. Enemy air strikes, RAM failures or weather delays are some of the processes which affect the ability of each aircraft to adhere to its planned schedule and route. In a physical sense, the primary activities are tracking the progress of a plane in flight and the tabulation and reporting of any deviations from its planned schedule so that any decision necessary to compensate may be made in a timely manner consistent with current priorities.

        e.   Arrival Airfield (AAF)

        The processes in AAF are similar in many ways to those in DAF. Arriving aircraft are queued for landing and unloading in a manner based upon the priorities of the theater commander. Although the process is in reverse, the availability and use of special tools and equipment is an important factor. Additional processes include the re-assembly and preparation of the cargo for immediate use in the combat area or preparation for intratheater transportation to users.

The biggest difference between AAF and DAF is that AAF is located in the hostile environment of combat operations. As a result, the combat activities of support troops in the area, fighter escorts and other means of denying the enemy the means to disrupt the air deployment are concerns of this subarea.

D. INTERRELATIONS BETWEEN AREAS

These divisions of the real world are an artificial construct designed to focus attention on one area at a time. The processes contained in each area are not independent of the processes in other areas. Rather, there are frequent impacts on the processes in each area by all other areas. These interrelations are as important as the processes themselves and they will be discussed in a general way in major areas interrelations. They will be discussed in a much more detailed way in subarea interrelations.

There will be no discussion of minor area interrelations. This is because the only first order interrelation between the sea and air areas is in the process of deciding what type of transport to use for each item to be moved to the theater of operations. Minor area interrelations are important effects but are beyond the scope of this thesis. This thesis examines a methodology for validating or testing contingency plans for military operations. It is

31

assumed that the plan has already designated the type of transport to be used by each item.

1. Major Area Interrelations

There are five major interactions between the three major areas. These are highly aggregated interactions that are multifaceted but important to a grasp of the big picture, and they are depicted in Fig. 2, Major Area Interactions. These interactions are:

a. The urgency for delivery of forces to the theater of operations and hence the urgency for mobilization of transportation assets. The combat (and political) processes in the employment area generate this urgency and mobilization responds.

b. Transportation assets as provided in the mobilization area to the deployment area.

c. Changes made by the theater commander in priorities of cargo (deployment) in response to combat activities.

d. Enemy actions which allow processes in employment command and control to be used in combat against friendly assets enroute or at the ports of debarkation and arrival airfields.

e. Interactions which result in cargo of all types being delivered to the theater of operations.

2. Subarea Interactions

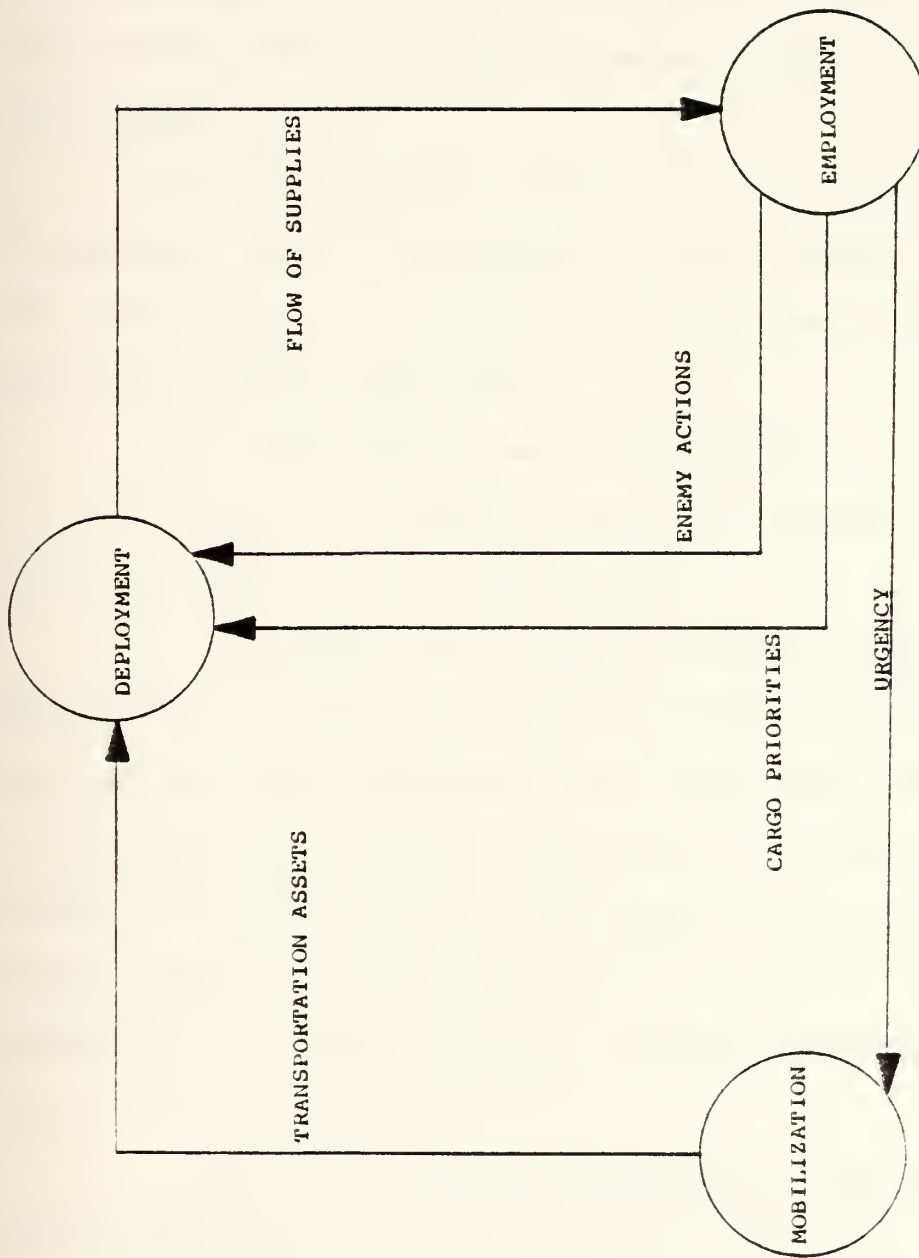There is no doubt that a case can be made for the existence of continuous interactions between all subareas.

32

Fig. 2. Major Area Interractions

However, most of these interactions are either not of interest from the large perspective or their effects are too small to be included in any practical sized study. The interrelations that are described in this section are those that have a major and immediate impact on the subareas they affect.

In order to give structure to this discussion the interactions will be organized by the subareas they affect. The subareas will be discussed in the same order in which they were earlier described.

a.   Interactions Among Sea Subareas

The sea subarea interrelationships are depicted in Fig. 3, Sea Subarea Interactions.

The ship mobilization subarea greatly affects the subareas in the deployment major area; however, almost none of the other subareas affect ship mobilization. There is an interaction between the balance of forces in the theater of operations and the urgency with which transportation assets are mobilized; however, this is almost impossible to quantify and is a second order interaction at best.

It is not surprising that the detailer subarea has the most interactions of all the subareas. It contains the command and control processes for the entire deployment area and is affected by practically every other subarea.
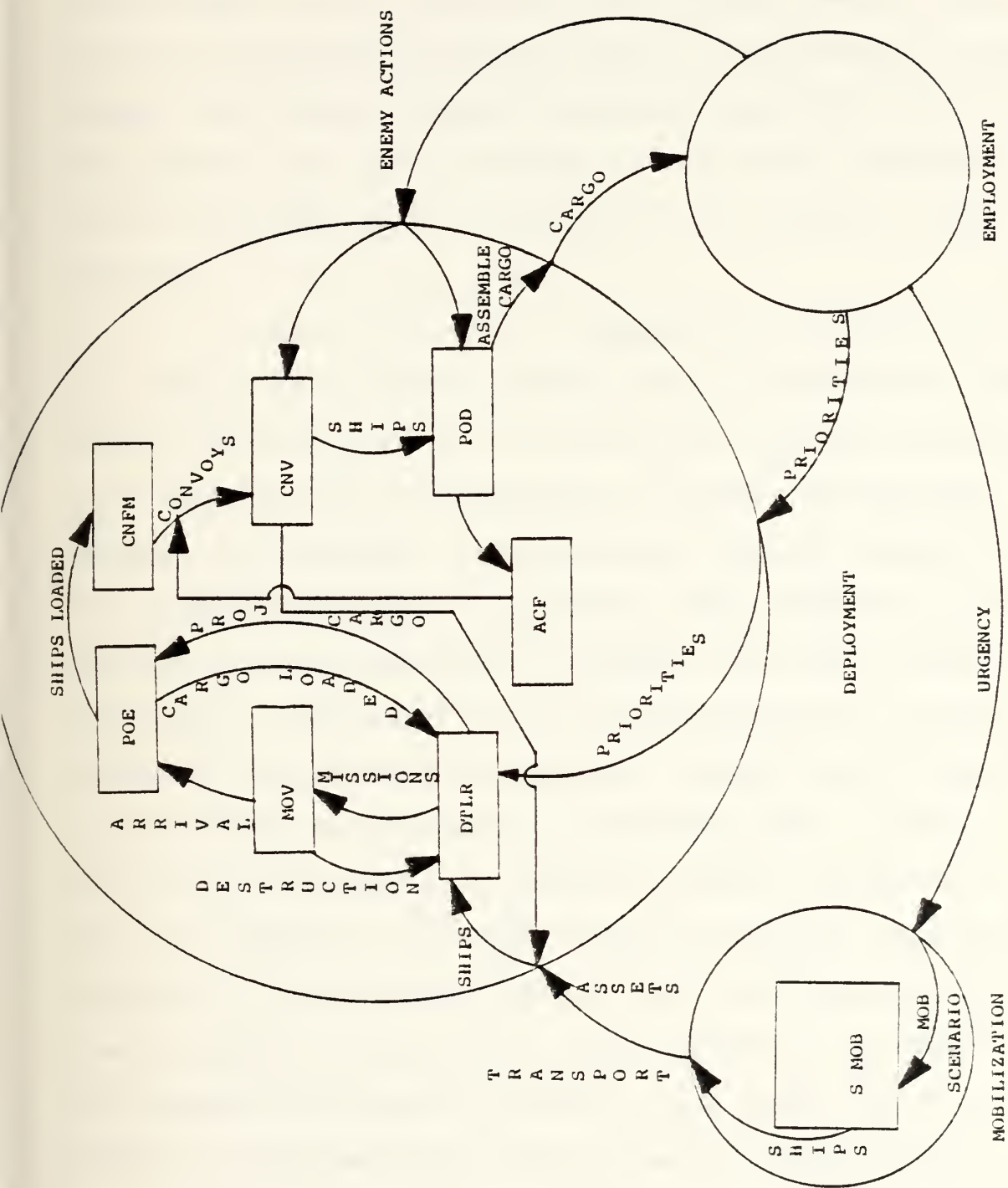
Fig. 3. Sea Subarea Interactions

The ship mobilization and convoy subareas result in empty ships being returned to the CONUS area. These empty ships are the resources that detailer uses to accomplish its objective of moving cargo to the theater of operations. The detailer subarea processes begin when the ship mobilization and convoy processes provide the information that a ship will soon be available to be assigned a new mission.

Once the detailer subarea has assigned a ship its mission, the detailer cannot merely ignore the ship and cargo from that point on. If at any time before the cargo is loaded the ship is destroyed or delayed, the detailer subarea must reexamine its options and assign another asset to transport the cargo in question. This results in interactions with the subareas of movement, ship mobilization, and convoy. Suppose that the ship mobilization or convoy subareas have informed the detailer subarea that an empty ship will soon be available in the CONUS area. If that ship is then destroyed or delayed, that will cause the detailer subarea to reassign ships to the cargo originally assigned to the destroyed ship. This could occur within the processes of ship mobilization, convoy or movement. If, however, the ship has picked up its cargo, there is no effect on detailer since ship and cargo were destroyed together. In this way the port of embarkation subarea also affects the detailer processes since it loads the cargo.

The employment major area affects the detailer subarea by setting and possibly changing the cargo priorities.

The movement subarea is only affected by the detailer subarea which assigns ships their missions to include to which ports of embarkation to move.

The port of embarkation subarea is affected by two other subareas. The movement subarea processes result in ships arriving at the port. The detailer subarea makes the decisions as to what cargo the ships will carry.

The convoy formation subarea is only affected by the port of embarkation subarea which provides loaded ships to convoy.

The convoy subarea is affected by three other subareas. The return convoy formation and convoy formation subareas result in convoys being organized with a rendezvous point designated, a rendezvous time determined, and a desti-nation for the convoy generated. The employment major area's enemy command and control processes cause enemy forces to attempt to interdict these movements. This results in combat in the convoy subarea.

The port of debarkation is involved in two major interactions with other subareas. The convoy subarea's movement process results in ships arriving at the port of debarkation. The employment major area sends enemy forces

against the port much as against the convoys in the convoy subarea.

The return convoy formation subarea is only affected by the port of debarkation subarea. This subarea's processes result in empty ships ready for the return voyage in much the same manner that the port of embarkation processes result in loaded ships ready for the voyage to the theater of operations.

b. Air Subareas Interactions

Figure 4, Air Subareas Interactions depicts these interrelationships.

Aircraft mobilization is virtually independent of each of the other subareas in the areas of air mobilization and deployment. It does, however, exert a great deal of influence on the other subareas. Primarily it serves to provide the locations and availability times of each aircraft. The attributes of these aircraft such as speed, range, and cargo capacity are used in the detailer subarea to make mission assignments.

Aircraft detailer has more interactions and feedback loops than any other air subarea and is easily the most complex set of processes. At the operation's inception, A/C DTLR makes initial assignment of missions to each aircraft based upon priorities as they exist at that time. Initial considerations are to marshall assets as
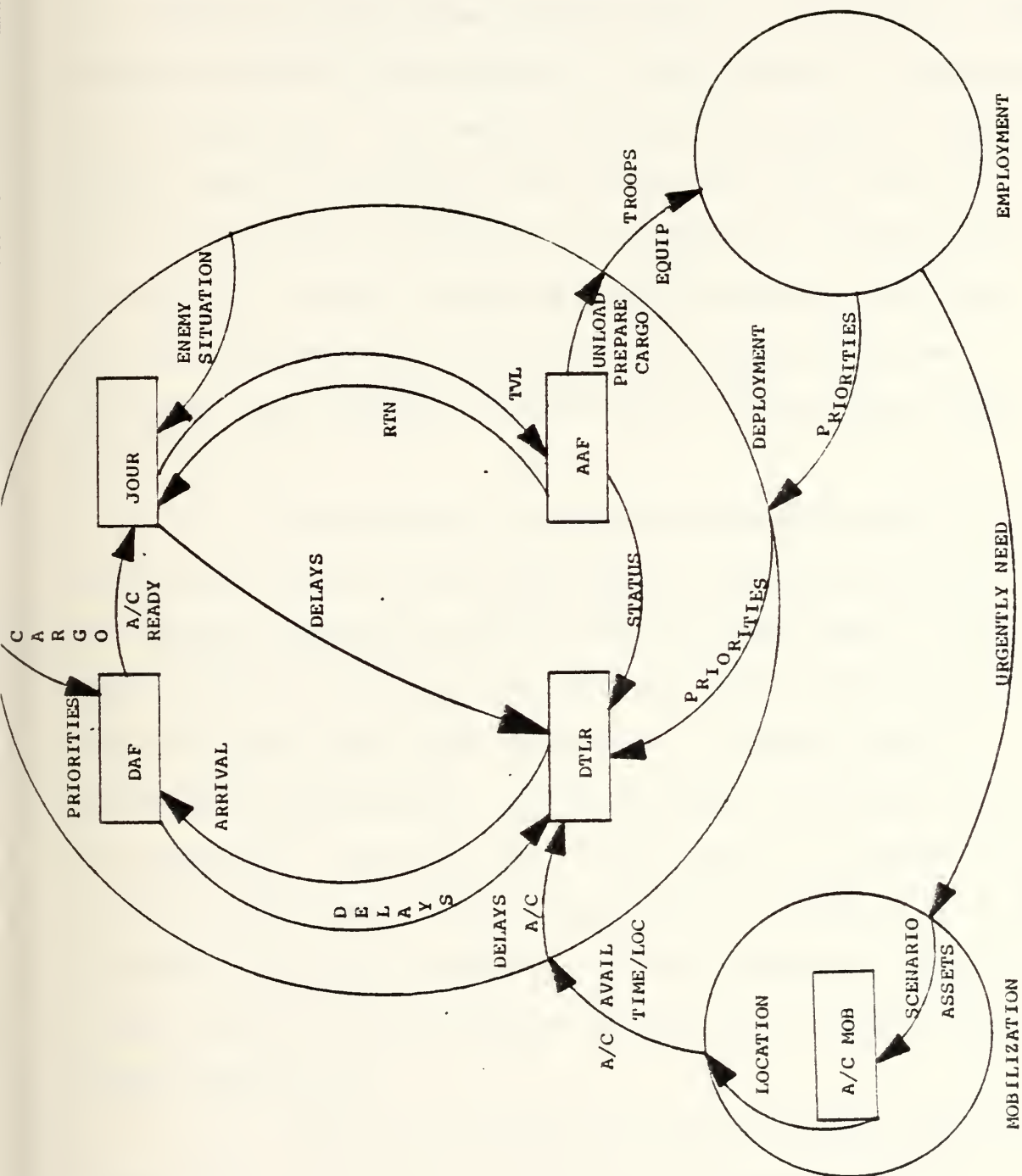
Fig. 4. Air Subarea Interactions

39

quickly as possible and transport troops and equipment to the theater in which they are to be employed. Subsequent events require that information be fed into A/C DTLR from all subareas so that the maximum amount of flexibility and responsiveness to requirements in the theater of operation can be provided. The amount of detail necessary to make the right decisions requires that each plane and cargo be tracked from the inception of the operation through each step that it takes. Feedback exists from DAF, JOUR, and AAF so that deviations from the critical path can be analyzed and compensation directed at the earliest possible time.

The subarea of Departure Airfield ties in with both DTLR and JOUR with essentially the same information. It receives expected arrival times for each type of aircraft in an information loop from DTLR and based upon the priorities for each type cargo determines a loading queue, schedule of maintenance, and crew rest or exchange if that is necessary. Coordination in the form of a feedback loop with A/C DTLR and a forward communication channel to JOUR provide up-to-date information on the scheduled departure time of each aircraft and the deviations, if any, that are being experienced.

JOUR is a flight path between points that is covered by a specific aircraft in the performance of an

40

assigned mission. The loops that it maintains with A/C DTLR and AAF provide each with exception information due to any deviation from schedule. It also interacts with any hostile activity or nonhostile act which causes deviation from plan. In each case JOUR acts as a messenger to relay the information through the loops it maintains with A/C DTLR, AAF and DAF.

AAF interacts with the employment area in addition to other subareas in air mobilization and deployment. This requirement for interaction is predicated on the location of the arrival airfield in the zone of operations which is controlled by the theater. In particular this coordination is necessary to prevent the scheduling and arrival into airfields that are too far from the locations specified by the theater commander for the employment of the equipment. Also of particular concern is the safety of the airfield for the conduct of operations which are relatively dense and thus good targets and chokepoints.

III. APPROACHES TO MODELLING THE REAL WORLD

Today, in order to attempt to validate the plans being made for a military contingency outside of CONUS, it is necessary to conduct a large CPX type exercise. This is very prohibitive in terms of both time and money. What is needed is a model of the real world that could be used to validate the contingency plans within the context of the assumptions that originally went into the plan and that necessarily must go into the model.

This model is necessarily very complex because of all the interrelations that exist in the real world. To be of value it must be automated so that small numbers of personnel can validate the many contingency plans that are generated every year.

A. SURVEY OF APPROACHES

The choices of methodology for use in the modelling are simulation and optimization. These alternatives may in turn be designated as either stochastic or deterministic and may be high or low resolution.

Resolution in this context is defined as the level of the system being represented. As an example, high resolution modelling represents the activities of the item system, such as a combat vehicle. Successive levels of lower

resolution aggregate the item system into platoons, companies, brigades, or other heterogenous organizations. The discriminant between levels of resolution is the amount of detail being represented. The choice of resolution level is dependent upon the effects and activities which the modeller wishes to examine. In modelling a corps operation, for instance, high level resolution which tracks individual tanks is inappropriate, but a lower level which resolves at brigade level may be ideal.

Stochastic simulation uses probability distributions of activities to be modelled. A "draw" from the appropriate distribution determines the occurrence of an event and a "draw" from an additional distribution provides the assessment. When used in conjunction with high resolution, it is very sensitive to the synergistic effects which may influence an activity. Its primary advantage lies in the large amount of detail with which each activity may be examined. On the other hand, the amount of detail may be so voluminous that major trends and meaning may be lost. In addition, a large number of replications is required in order to achieve the desired precision.

In contrast, deterministic simulation uses only the probability of the occurrence of some event. It is often referred to as an expected value model and requires only a single replication. The amount of computer time required

may be much less than that of stochastic simulation, but
the tradeoff for responsiveness and simplicity of output
results in less detail and diminished sensitivity to syner-
gistic effects.

Simulation models may be either very high resolution or
low level and highly aggregated. Depending upon the amount
of detail required, the acceptable level of aggregation may
vary. Optimization, on the other hand, requires aggregation
of processes or types of cargo. It is unable to track
specific items of interest because the extremely large
number of variables makes the problem too big. The trade-
off is between extremely descriptive detail and optimal
allocation of resources. Cargoes are typically aggregated
into tons or some generic class for description. Likewise,
transportation assets are grouped by type of aircraft and
the activities are in terms of ton-miles per day as an
example. The advantages of optimization are the efficient
use of transportation assets to affect optimal accomplishment
of directed tasks and the capability to determine the worth
of one additional unit of resource.

In the simulation approach the problem of modelling
the real world is broken down into the problem of simulating
each small piece of the real world and then appropriately
tying the pieces together. There are two ways to tie the
process together:

1.   The first way is through the time step approach. This approach consists of looking at time as small jumps or steps. Within these steps all activities occur. The processes are tied to the time step and repeated every time step whether needed or not. For example, the model goes through a process to decide whether or not a ship is destroyed in each time step. This system provides a framework within which the models of subareas may be organized; however, a great deal of time is spent in bookkeeping for time steps in which nothing occurs.

2.   Another approach to organizing the parts of a model is event scheduling. In this approach the event such as destruction of a ship would be entered in an event clock and when the event clock reached that time, the appropriate subarea models would be sequenced. This approach has the advantage that it does not waste effort on unnecessary bookkeeping. However, it does have the disadvantage that it does not provide as organized a flow as the time step approach.

This thesis is limited to the discussion of the high resolution approach. Either stochastic or deterministic simulation is employed, dependent upon the desired effects to be examined. A possible architecture which utilizes this methodology is discussed.

B. THE HIGH RESOLUTION APPROACH

One approach to designing a model of a military contingency is to utilize an approach that attempts to follow all the ships, aircraft, and major combat systems as they move about the world.

The motivation behind such a model is that it allows precise actions to be modeled. An example is the destruction of a cargo ship with 12 tanks and 15 APC's of the 1st Battalion 72nd Armor on board. This has two advantages. It is more comprehensible to a person who is not quantitatively inclined and also it provides for precise interactions between weapons systems on the battlefield. This approach has several disadvantages. It requires a large computer, a long period of time to run, and a very large and detailed data base from which to operate. In addition, it outputs so much detailed information that it may be hard to digest and compare.

In organizing this high resolution approach to modelling a military operation, the functional areas of the real world are modelled individually. These operations are then tied together by appropriate input/output flows and sequencing. The subareas have been modeled by modules, the minor areas by sections, and the major areas by models.

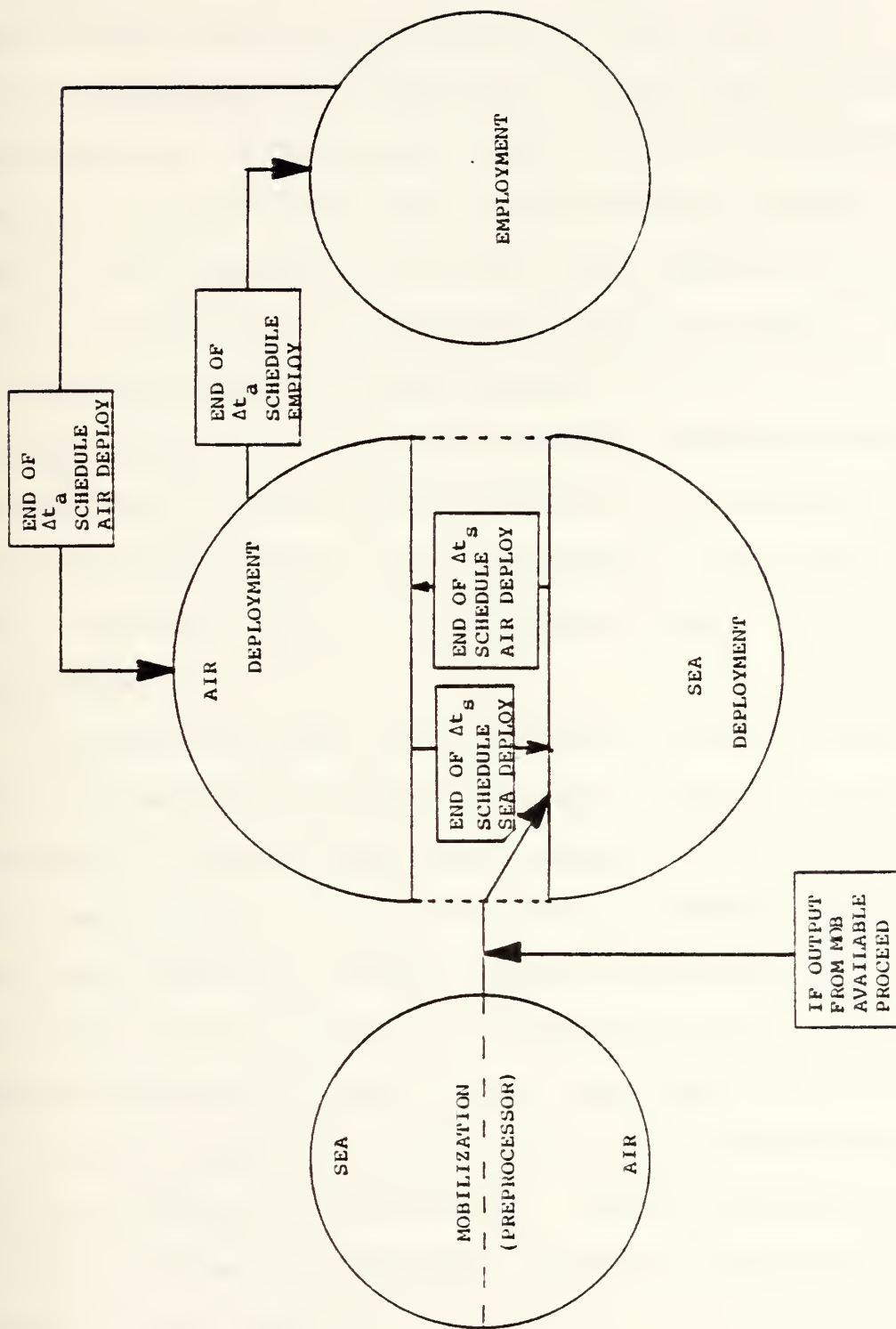The overall interoperation of such an approach is shown in Fig. 5, Model Level Interoperation. Mobilization is a

Fig. 5. Model Level Interoperation

47

free standing model that is run as a preprocessor for the
rest of the models. This eliminates any explicit connection
between the mobilization urgency and the battlefield situa-
tion. Therefore, it is important for the user to examine
his battlefield results and compare them to the mobilization
scenario that was input into the mobilization model. If
they are not compatible, then the user needs to suitably
modify the mobilization input and rerun the entire system.

This particular form was adopted in order to allow many
individual parts to run independently. Because of the
complexities of the process involved, it is doubtful that
all these parts can be run at one time on one computer.
This structure allows the mobilization model to be run in-
dependently.

The sea deployment section can also be run independently
for long period of simulated time Δt_s. This is because the
response of the sea deployment section to other parts of
the overall model is relatively slow. However, the sea
deployment section's output affects the employment model
relatively swiftly so it is important that the sea deploy-
ment section be run prior to the employment module.

The air deployment section can be run independently,
only for a much shorter time Δt_a. This is because the
response of the air deployment section to the employment
model is much faster.

A reasonable figure for the ship run time Δt_s seems to be about three weeks while the air run time Δt_a should be held to twenty-four hours.

Once the mobilization model has run, its output is stored and the remaining models can be run at any time desired. The first section to run is sea deployment. It is run by itself for a period of simulated time referred to as Δt_s (Fig. 6). This time is set by the user. Once the sea deployment has run for Δt_s, the air deployment runs for simulated time Δt_a. At the end of Δt_a the employment module runs for a period of time Δt_a. At this point the air deployment section and the employment model are at the same simulated time. Sea deployment is far ahead in simulated time.

The air deployment section is then run for another Δt_a. But before it does, it evaluates the employment model's combat results and adjusts its priorities if necessary. The air deployment section can adjust to pick up any item of cargo not already picked up by the sea deployment section in its earlier run. Once the air deployment section has run for a simulated time of Δt_a, the employment model is again run until the times are again equal. This process is continued until the simulated time is set at Δt_s.

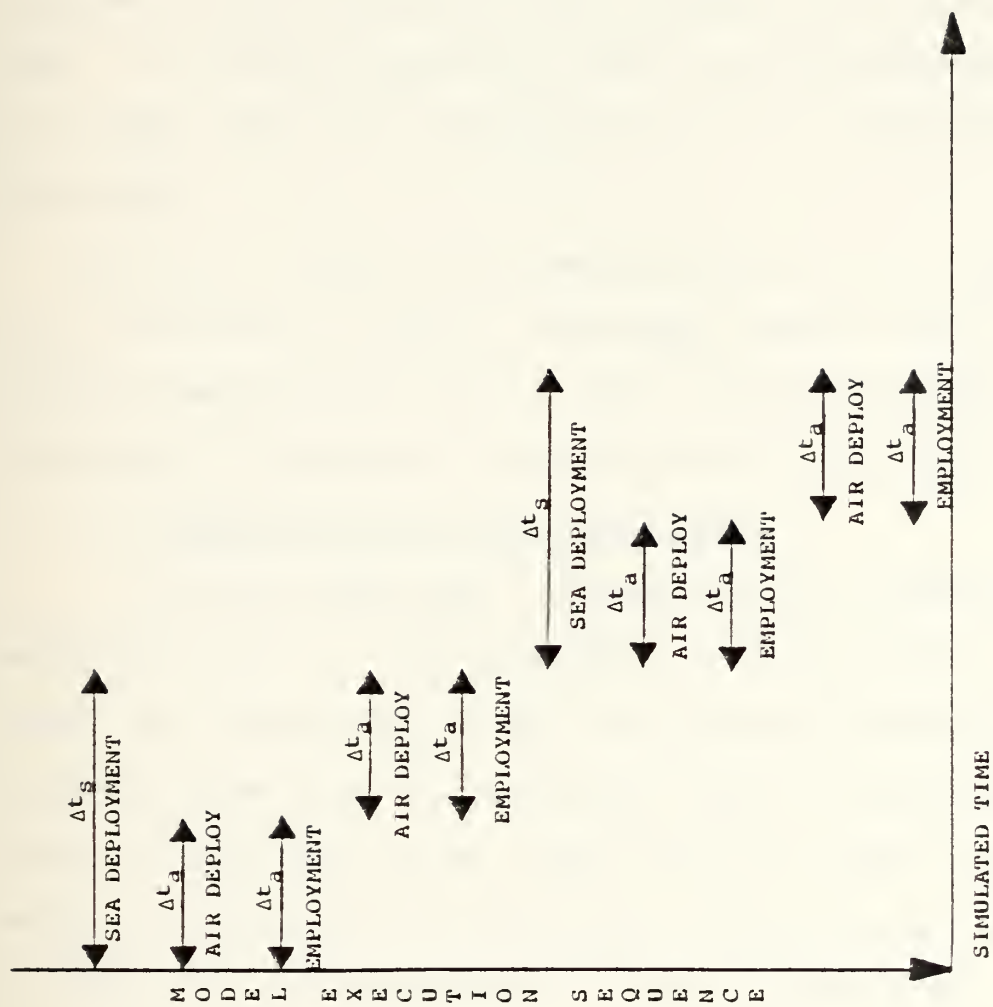Once the series of runs by the air deployment section and the employment model are finished, the sea section is

49

Fig. 6. Model Section Sequencing

50

run again. However, it first evaluates the combat results like the air deployment section did and modifies its priorities as necessary. The sea deployment section also deletes any cargo from its list that has been air delivered because of modifications to the original plan by air deployment. It adds any items that have not been delivered because of a shift from air to sea delivery by the necessities of the combat.

Once the sea deployment section has run for another Δt_s, the series of the air deployment section and the employment model begins again. This process continues for the length of simulated time specified by the user.

1. Sea Mobilization and Deployment

The sea deployment interoperation of modules is depicted in Fig. 7, Sea Deployment Interoperations. As shown, the overall driver is a time step of duration Δt_d with the areas show following each other in execution. The basic function of the time step is to force the detailer module to periodically look at the ships that are returning to CONUS via a return convoy or ship mobilization. For this reason Δt_d must be less than the time required for a ship to return from the theater of operations. Three days seems reasonable for almost any contingency. The flow is self explanatory as depicted.
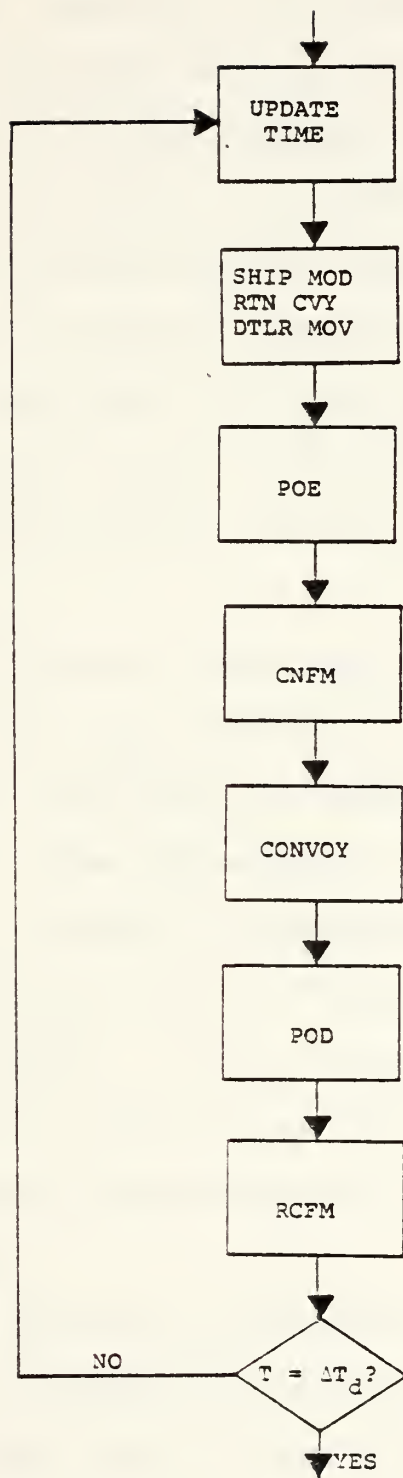
Fig. 7. Sea Deployment Interoperations

52

Figure 8, Sea Deployment Detailer Scheduling shows the interoperation of the box labeled Ship Mobilization, Return Convoy, Detailer, and Movement. This flow is event scheduled. First the data from the ship mobilization module prior run is preprocessed to schedule arrivals at arrival control nodes and the destruction of ships by the enemy from ship mobilization. Then the return convoy pre-processor is run for all return convoys that were in the system as of the end of the last time step. The data from this run is then entered in the event clock in the form of ships arriving at arrival control nodes or being destroyed enroute.

Once this has been done, detailer is run to assign a mission to all ships that will arrive at the arrival control node, regardless of whether that ship will later be destroyed. Then the movement module in entered when two events occur. First, the movement module determines when the next event will occur. The second event could be one of several things. It could be an item already in the event clock or it could be an item that movement will generate such as the destruction of a ship or the end of the time step.

Once movement has determined when the next event will occur, it updates the position of all ships in it to the time of that event. Three things can then occur:
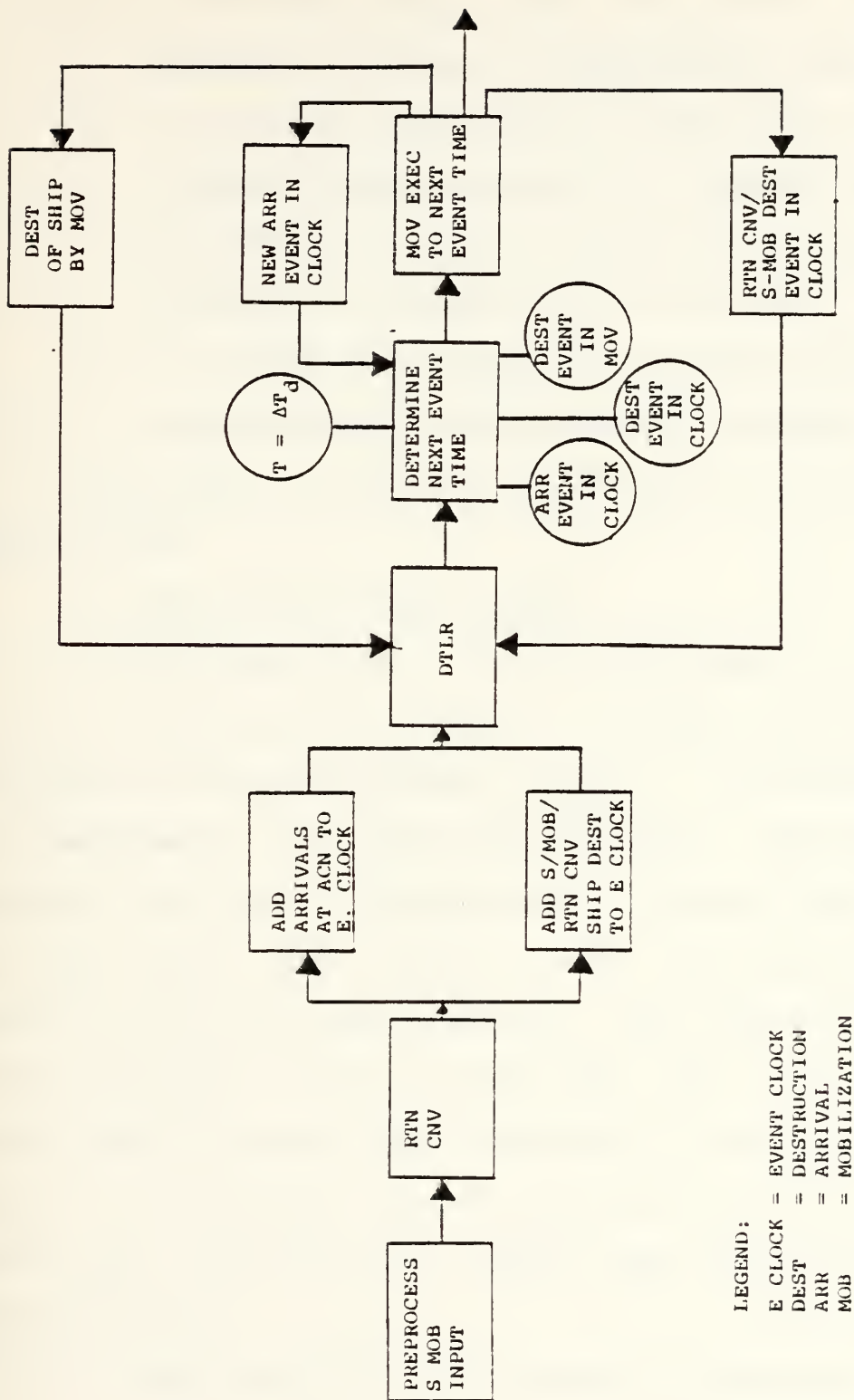
Fig. 8. Sea Deployment Detailer Scheduling

LEGEND:

E CLOCK = EVENT CLOCK
DEST   = DESTRUCTION
ARR   = ARRIVAL
MOB   = MOBILIZATION

54

(1) If the time step is over, the section pro-
gresses to the port of embarkation module.

(2) If a ship is destroyed in either the return
convoy, ship mobilization, or movement modules,
the detailer module is reentered to shift
missions in response to the ship loss.

(3) If a ship has arrived at an arrival control
node then the process reenters movement.

A detailed discussion of the functions in each
module follows.

a. Ship Mobilization (S MOB)

Ship mobilization is the only module in the sea
section of the mobilization model. It models the ship
mobilization subarea as depicted in Fig. 9. The module
runs independently of all the other modules. Its output
consists of two files. The first is the event clock file
that lists time of event, type of event, and ship identi-
fication to which the event pertains. The second file is
the ship estimated time of arrival file. This file contains
the ship identification, time available at the initial
location, the estimated time of arrival at the arrival
control node, and the arrival control node to which this
ship will return.

The operation of this module is depicted in
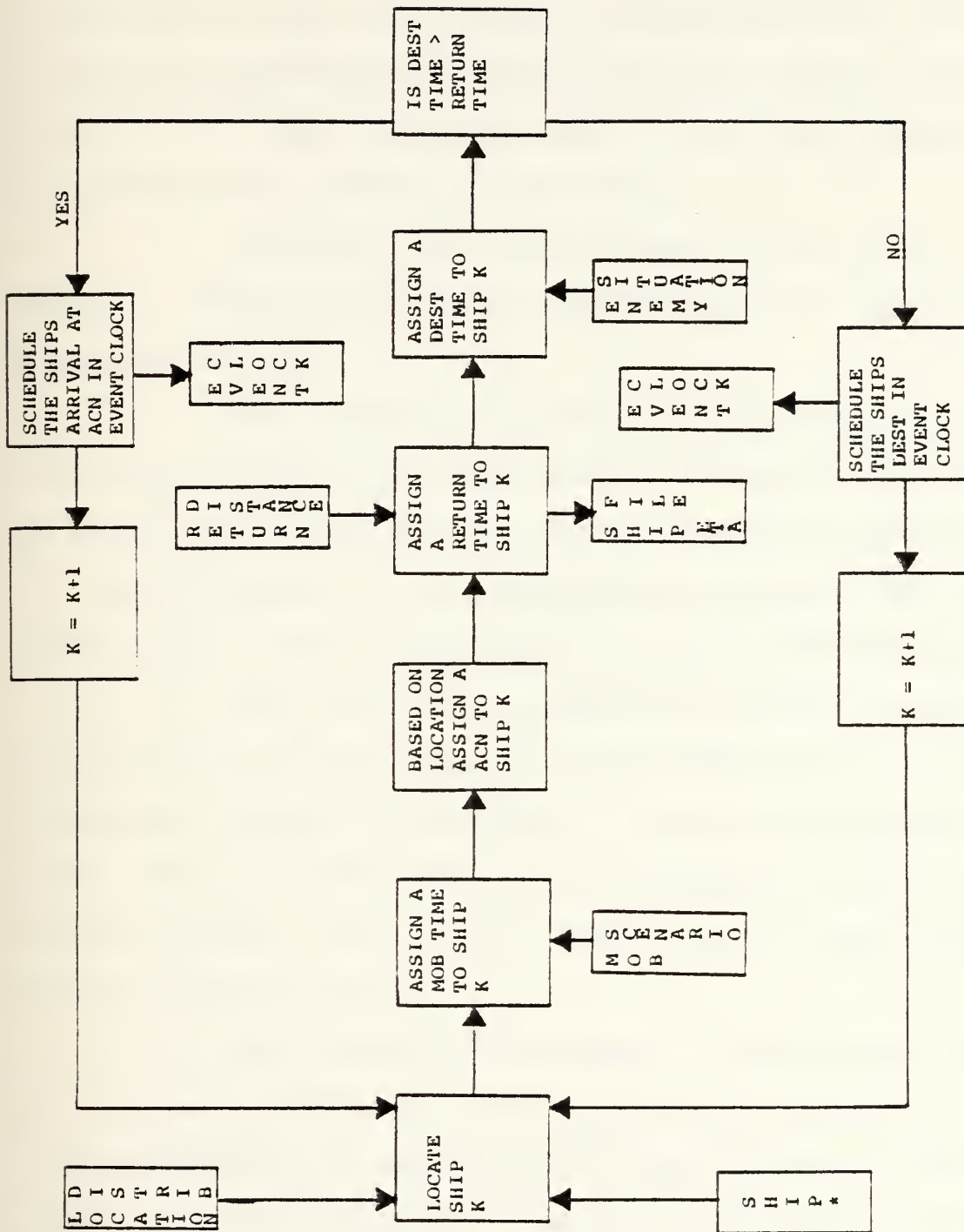Fig. 9, Ship Mobilization. The variable K is a counter

Fig. 9. Ship Mobilization

that is set to equal 1. The ship mobilization module looks in the file SHIP* and by using the location distribution type entry in that file for ship K determines the initial location distribution of the ship from the location distribution file. Then the module uses a Monte Carlo simulation to determine the location of the ship.

In general this can be done in any level of detail. The ship's location is specified by the area which contains the ship.

Once a ship is located it is assigned a mobilization time based on its mobilization category (to be found in SHIP' and the mobilization scenario. This is accomplished by a table look up in the mobilization scenario file. This mobilization time is then written into the SHIP ETA file.

Next the ship is assigned an arrival control node based on its location. In this example that is simple since each location is assigned its own arrival control node. There are four nodes, each corresponding to one of the four areas. This arrival control node is then written into the SHIP ETA file.

Then the ship is assigned a return time. Based on the mean and variance given in the return distance file, a return distance is determined and when divided by the ship speed gives the return time which is written into the SHIP ETA file.

Using the proper destruction rate from the Enemy Situation file, a time to destruction is then determined for the ship. If this time is greater than the return time, it is ignored and the return time entered in the event clock. If this time is less than the return time, the time to destruction is entered in the event clock.

b. Ship Detailer (S DTLR)

This module assigns missions to ships based on some objective function or priorities system. The example shown here is a very rough first cut. It is presented to demonstrate the module's function, but has several demonstrable shortcomings that will be discussed later.

The first thing that the ship detailer module does is decide why this module was called (Fig. 10). If the normal progression of simulated time initiated the call into the ship detailer module, no special action is required. If the destruction of a ship caused the entrance into this module, then the cargo file is changed to reflect that the cargo assigned to the ship destroyed is now unassigned.

Next the cargo file is searched and a file is compiled of all unassigned cargo and of cargo assigned to ships not yet in their port of embarkation. This file is called TEMPORARY CARGO. TEMPORARY CARGO is then searched in turn to determine K, the highest priority of any cargo in that file. Then all assignments for all cargo in the
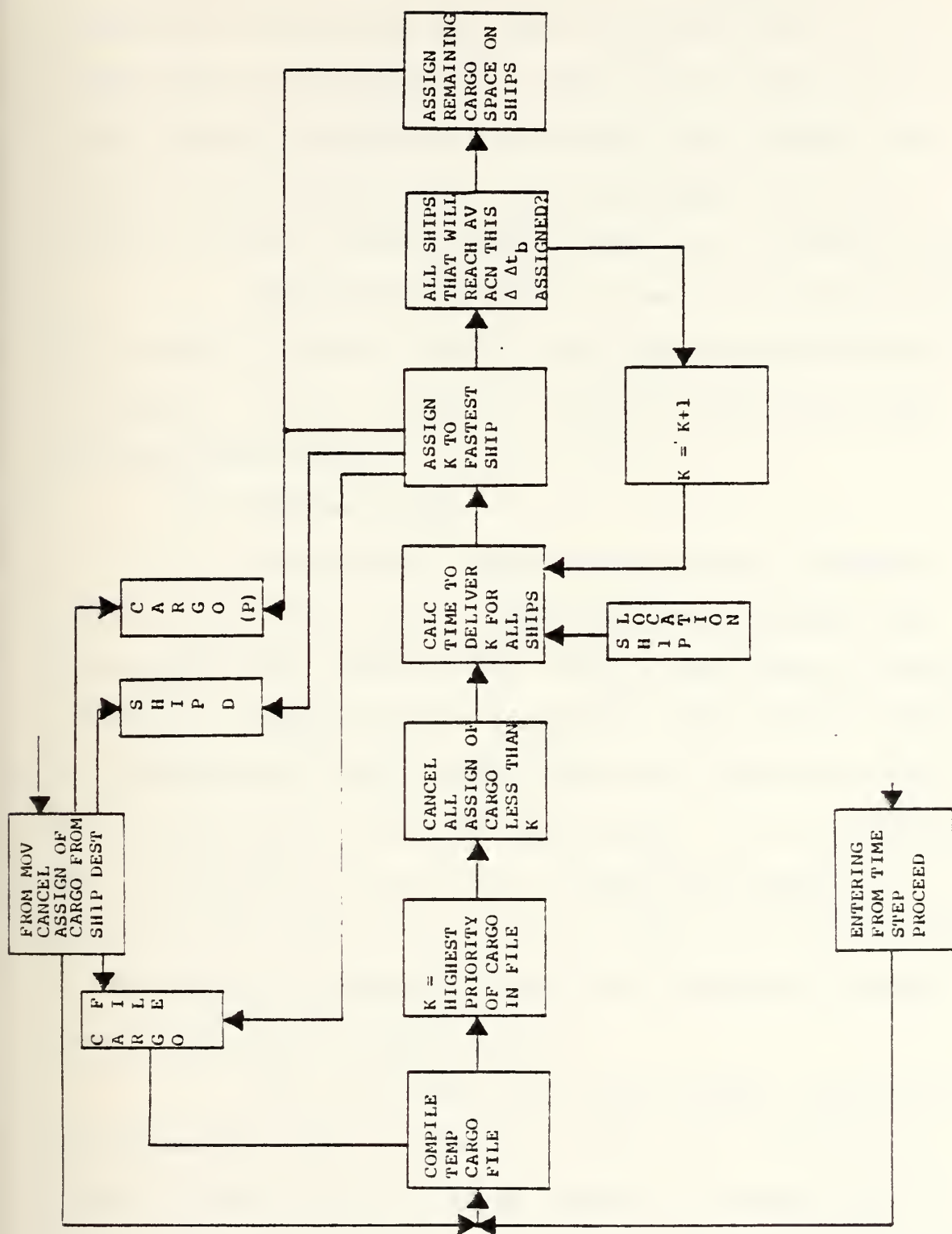
58

Fig. 10. Ship Detailer

TEMPORARY CARGO file are cancelled. The ship detailer module next calculates the cargo K delivery time for all ships that are appropriate to carry cargo K and with any cargo capacity remaining. The module then assigns that cargo to the fastest ship. This assignment takes the form of entries into the CARGO, CARGO (P), and SHIPD files.

Detailer then checks to see if all ships that will reach an arrival control node this time period are assigned. If not, it sets K = K+1 and assigns the next priority cargo item.

c. Movement (MOV)

The movement module simulates the movement of ships in the CONUS area. Unlike the other modules that move ships, this module keeps track of the actual locations of ships. It does this to enable the ship detailer module to calculate the time it would take for a ship to reach a port other than its current destination. It is not necessary to do this in the convoy or ship mobilization modules since the arrival control nodes are picked in such a fashion as to necessitate the ship's movement through them to any port of embarkation.

The first thing that the movement module does is decide how long it should run (Fig. 11). Based on a rate of ships killed in CONUS waters, it assigns destruction times to all ships. However, it ignores these times
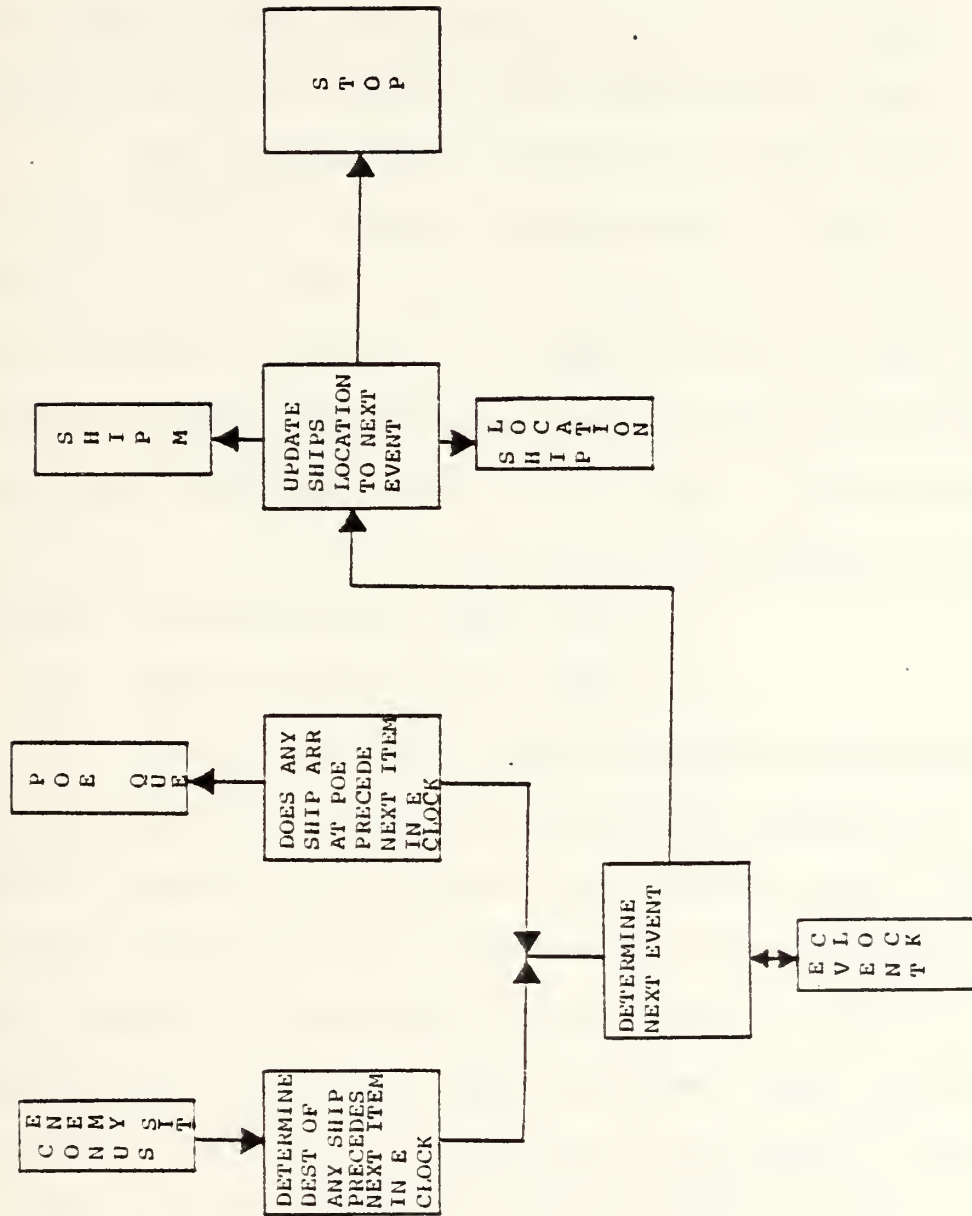
60

Fig. 11. Movement

61

if they exceed the time to the next event in the event list. It also determines the arrival times for the various ships at their designated ports of embarkation. It ignores these arrival times if they are greater than the next event in the event list or the smallest ship destruction time.

This module then determines the next event, either an arrival at a port of embarkation, a ship's destruction, or an event already in the list. If the event was not already in the list, it adds the event to the list. The movement module then updates the position of all ships to the time of the next event in the list. If this event is an arrival at a port of embarkation, this fact is noted in the port of embarkation queue file.

d. Port of Embarkation (POE)

This is the module that simulates the activities at the loading port. These activities are described in the port of embarkation subarea. This module uses an event scheduling driver much like that used in the detailer-- movement section. This driver is depicted in Fig. 12, Port of Embarkation. There are three processes that occur in this module. They are: (1) arrivals are placed in the event list, (2) the resource allocator decides what to do next, and (3) the update process updates the ship and cargo status.
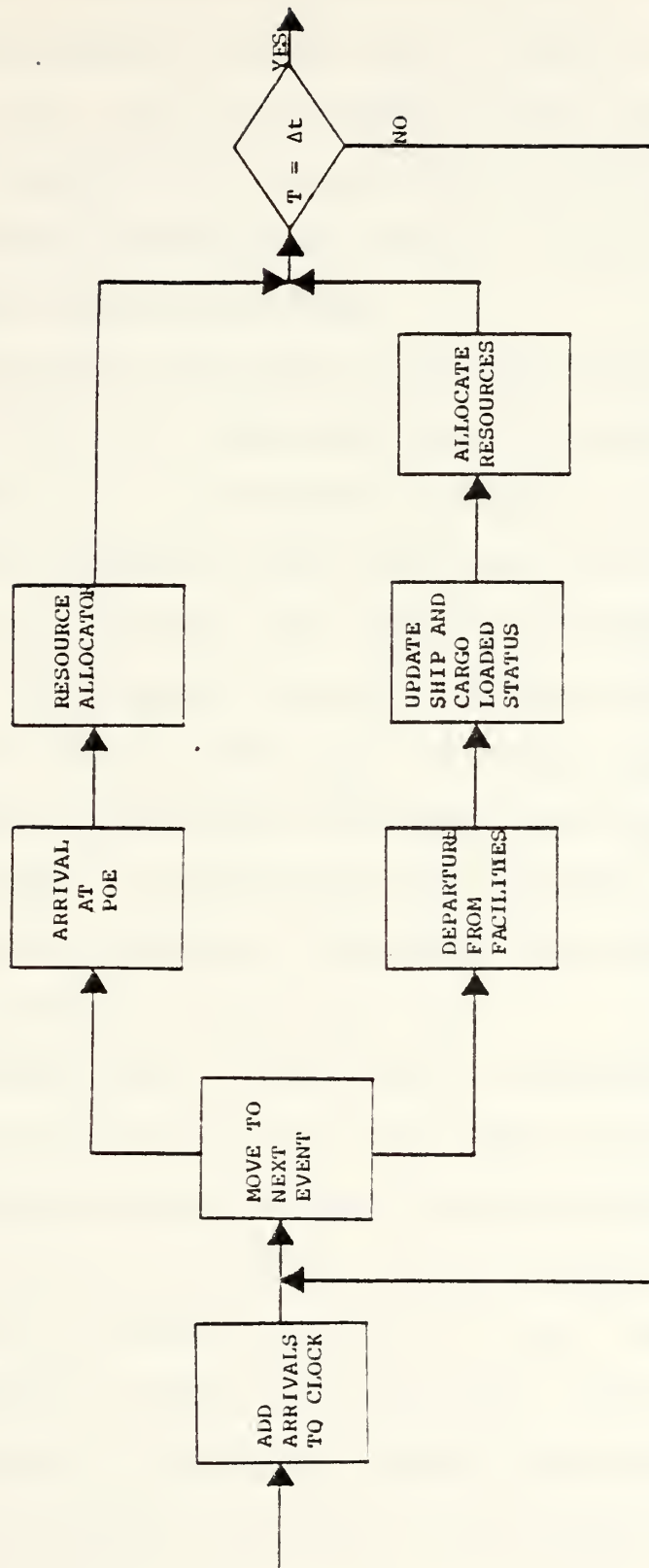
Fig. 12. Port of Embarkation

63

The first process takes the Port of Embarkation Queue file and schedules the arrival of ships at the port in the event list. This is necessary so that the resource allocator can schedule the entering ship to load ahead of any ships already in the queue that have cargos of less importance than the entering ship.

There are two types of events that can occur in the event list: (1) The event can be an arrival of a ship at the port or (2) it can be a departure of a ship from one of the loading or servicing facilities at the port. If the event is an arrival, the resource allocator process is initiated. The resource allocator checks to see if there are facilities available that meet the ships loading or servicing needs. If none are available, the ship is placed in a waiting queue. If facilities are available, the resource allocator schedules a departure time from that facility for the ship in the event list.

If the event in the list is a departure by a ship from one of the port facilities, then the update process changes the ship's status to either waiting in queue if the ship is not yet completely ready for sea, or to available for convoy if the ship is ready for sea. The cargo's status is changed to loaded if appropriate. Then the resource allocator is called to schedule any ships in the waiting queue for which facilities are available.

Once the departure or the arrival sequence of processes is completed, the module checks to see if this Δt_d has elapsed and if so, exits this module. If not, the module proceeds to the next event in the event clock.

e. Convoy Formation (CNFM)

The version of convoy formation shown here is crude. There needs to be more work done on determining optimal convoy size and configuration. However, this version of the convoy formation module demonstrates all the necessary input and output.

First this module orders all the ships in the ships loaded file by available time (Fig. 13). Then it goes down the file until it reaches its required convoy size or until the elapsed simulated time between the first ship available and the one presently being scanned exceeds a maximum waiting time. At present, the convoy size and maximum waiting time are user input. In future versions this could be calculated by the module based on risk and delivery time for the cargo. Once the above processes have generated a possible convoy, this module looks to see if enough escorts are available. The minimum level of escort necesary is a user input.

Once the convoy has been designated, a rendez-vous point is picked. The time to this rendezvous point is computed for all ships. A time to destruction is computed for all ships based on the CONUS area kill rate. If this
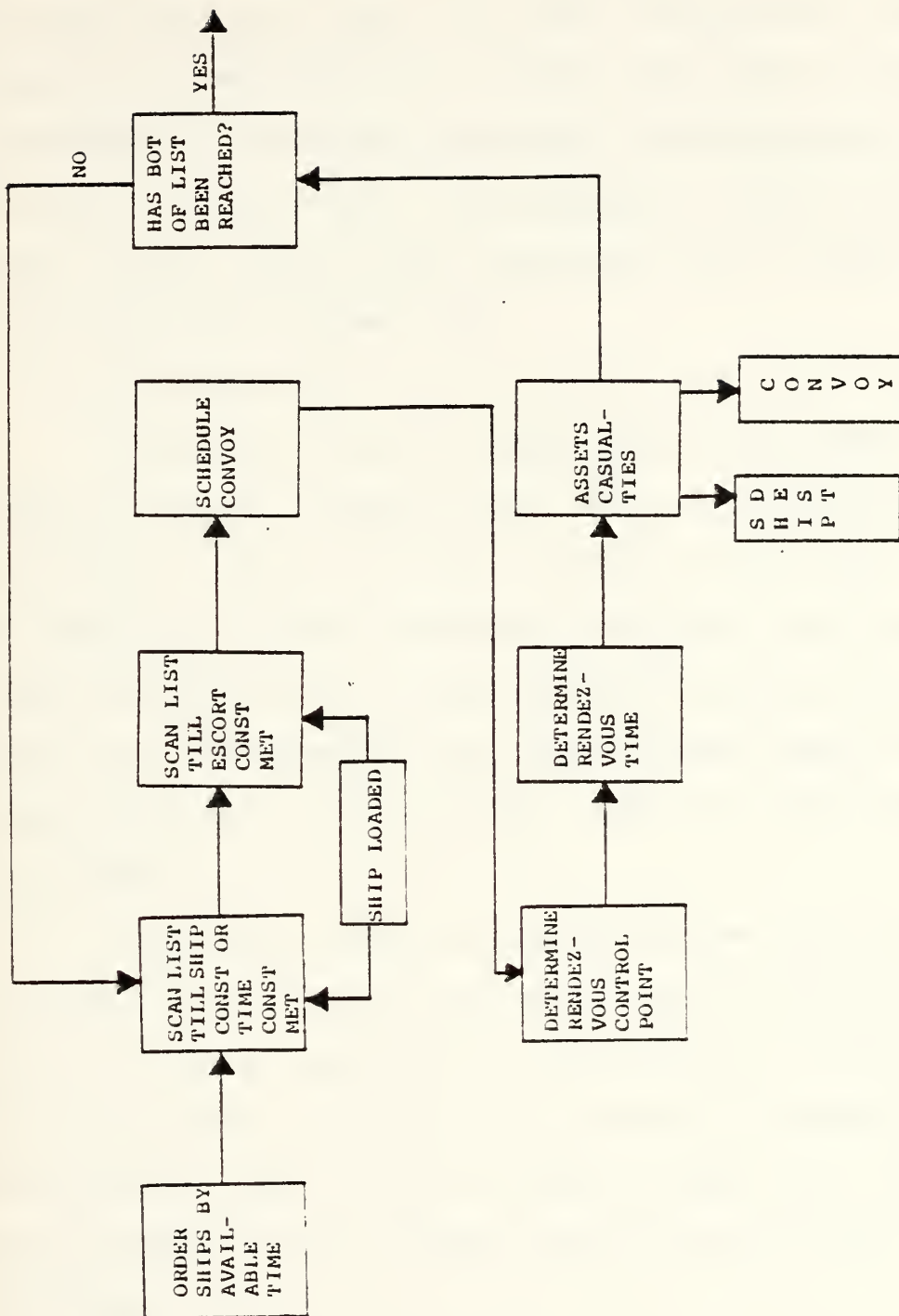
65

Fig. 13. Convoy Formation

66

time exceeds the travel time, it is ignored. If this time is less than the travel time, the ship's destruction and cargo carried is written into a model output file called ships destroyed. Otherwise, the ship's identification is written into a convoy file. The rendezvous time is computed to be the arrival time at the rendezvous point of the ship with the latest ship loaded time.

f. Convoy (CNV)

Convoy and return convoy modules move ships to and from the theater of operations. The only difference between enroute convoy and return convoy is that return convoy reports the results somewhat differently than convoy and convoy moves smaller subconvoys into the ports of debarkation from the release points while return convoy module turns the ships over to the movement module at the arrival control nodes.

The convoy module first determines the slowest ship in the convoy and sets the convoy speed to that ship (Fig. 14). It then stochastically determines a release point in the general vicinity of the theater of operations. It calculates the time for the convoy to reach the release point by determining the distance and dividing by the speed of the convoy.

Next, based on the enemy situation, the module determines a time to destruction for each ship. At present
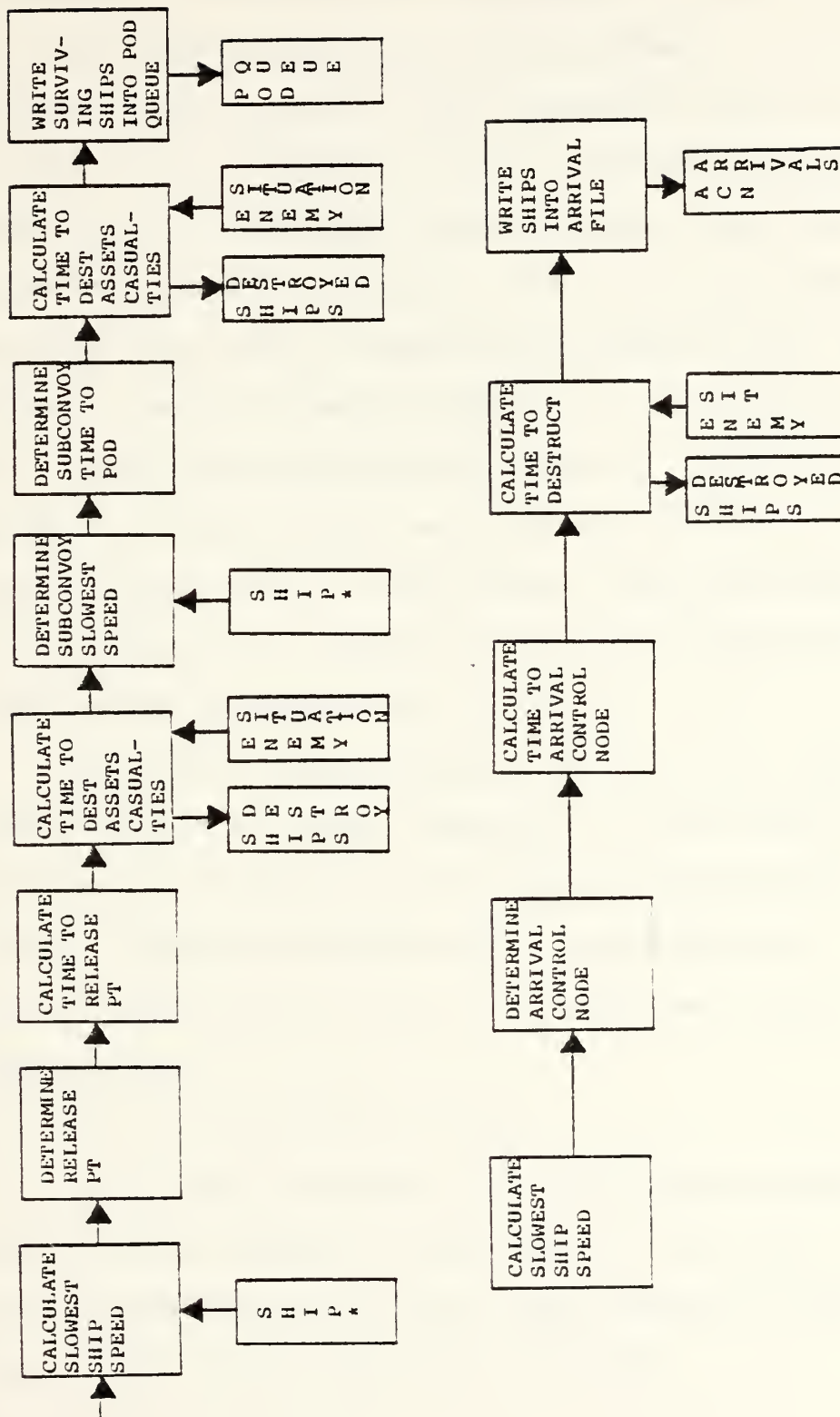
67

Fig. 14. Convoy

68

this consists of an aggregated kill rate for the entire
voyage. However, it would not be difficult to vary the
kill rate for different portions of the movement. If the
time to destruction is greater than the time to reach the
release point, it is ignored. If not, the ship's destruc-
tion is written into the ships destroyed file. Once this
is done the convoy module groups all the surviving ships
into groups by their port of debarkation destinations. The
slowest ship in each of these subconvoys is determined and
the time to reach the various ports computed. Then in a
fashion similar to the earlier main convoy, the time to
destruction for each ship is determined. Surviving ships
are placed in the port of debarkation queue and destroyed
ships in the ships destroyed file.

The return convoy portions function the same
as the first section of convoy; however, in this case all
ships are given a projected arrival time at the arrival
control node. Then the ships that are destroyed are
placed in a special file for use by the detailer return
convoy preprocessor.

g. Port of Debarkation (POD)

This module represents the activities at the un-
loading port in the theater of operations. It is very simi-
lar to port of embarkation with the added factor of enemy
attacks against the port facilities and ships.

As shown in Fig. 15, Port of Debarkation, this
module is exactly like the port of embarkation module except
for the inclusion of another possible event and two processes.
The event is the attack event. The processes are the
scheduling of attacks and the attrition process. The
attack scheduler considers the enemy situation provided
by the employment module and then schedules attacks for the
next Δt_d. It places these events in the event clock and
marks them as attacks.

The attack event sequence begins with the attri-
tion process that damages and destroys ships and facilities.
The the resource allocator is called to reassign the re-
maining facilities.

h. Return Convoy Formation (RCF)

The return convoy formation module functions
exactly like convoy formation. The ship unloaded file is
used for input and the escorts, waiting time, and convoy
size constraints can be changed to reflect the danger of
staying in a port subject to enemy attack.

2. Air Mobilization and Deployment

In real world terms, the purpose of the processes
in air mobilization and deployment is to meet the needs of
the theater commander. This is done by the assignment of
missions and the scheduling of resources in accordance
with current priorities. In a modelling sense, accurate
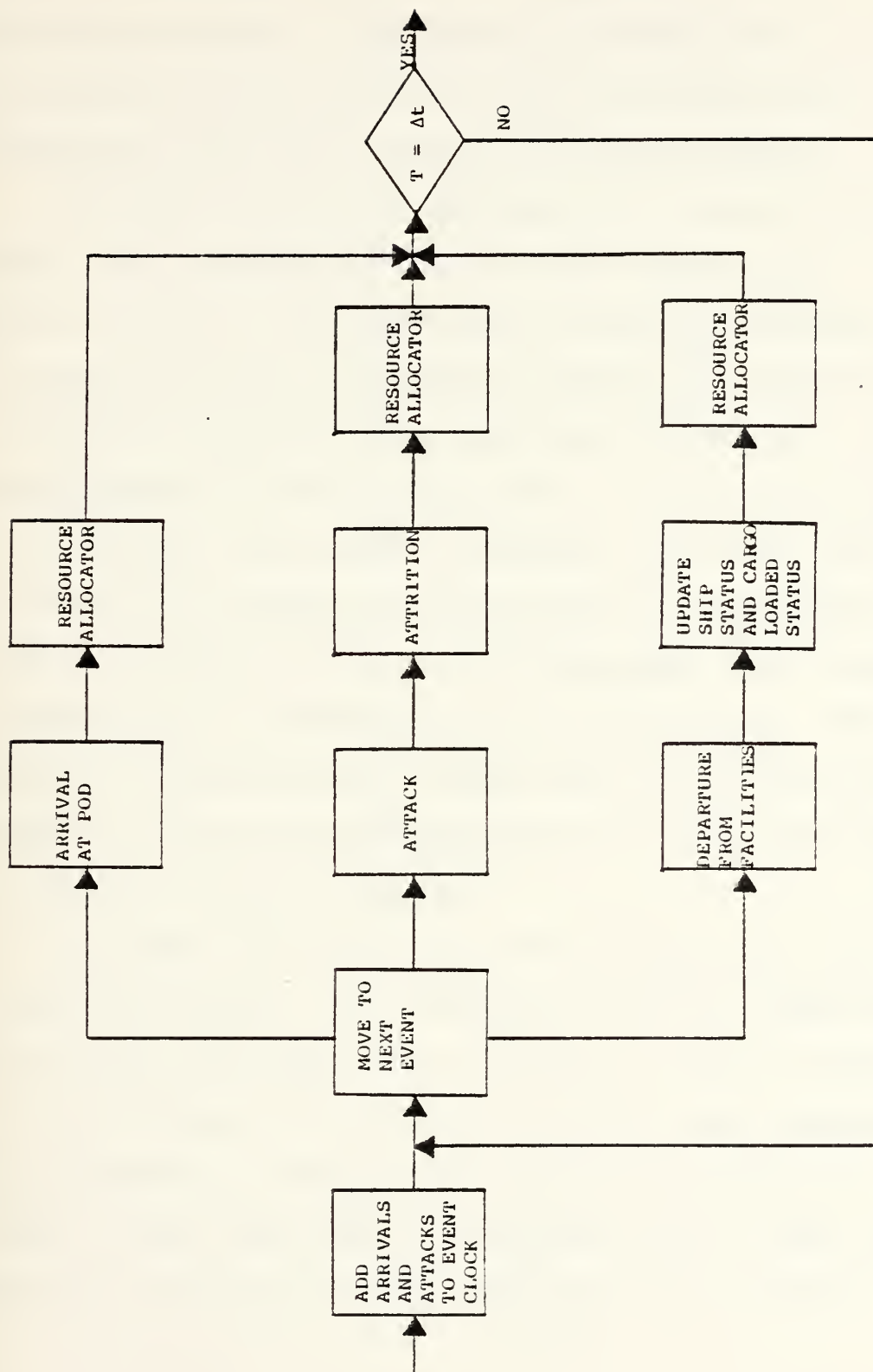
70

Fig. 15. Port of Debarkation

representation of these interactions and interdependencies requires that the methodologies be compatible with the effects being modeled. This section discusses the use of high resolution simulation with event step sequencing as an appropriate approach to modelling these processes.

Air mobilization and deployment are modeled by five modules. The interdependencies of these modules are depicted in Fig. 16. The event step sequencing requires the Aircraft Detailer (A/C DTLR) to examine the status of the deployment system whenever specified events occur. At each occurrence, A/C DTLR reevaluates the current situation and in accordance with current priorities makes any decisions necessary to affect changes in mission assignments. A/C MOB is a module external to Air Deployment that can be run independently of the modules in Air Deployment. Its function is to mobilize the aircraft that A/C DTLR will have available for mission assignment and to list the time that each aircraft will be available.

A/C DTLR also interfaces with the employment model and the S DTLR module. The interaction with the employment model provides the capability to respond to urgent requirements in the theater of operations with the rapid response of airlift assets. Missions are altered as necessary by A/C DTLR to meet these needs. Interface with the SHIP DTLR enables the diversion of cargo from sea to air transport
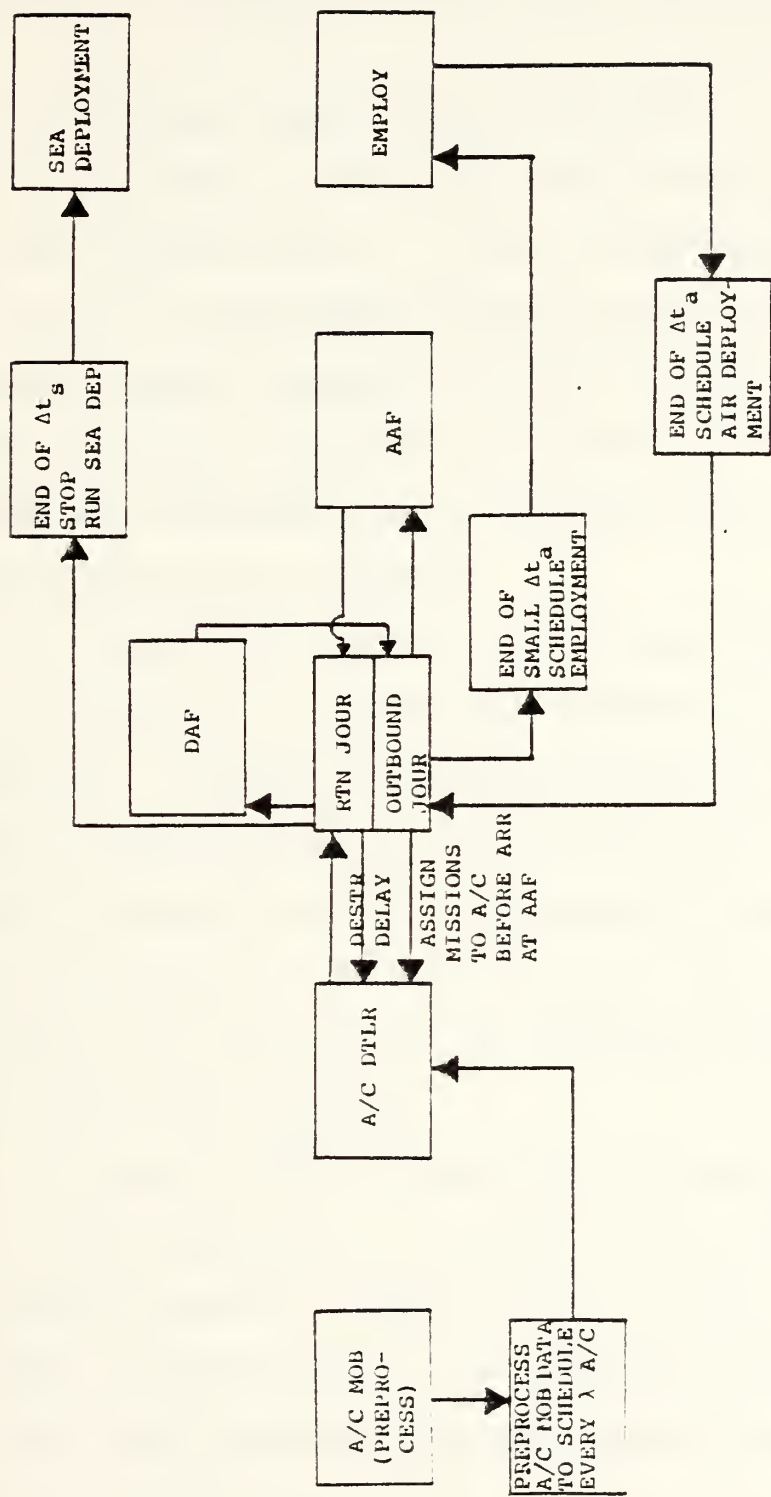
Fig. 16. Aircraft Mobilization and Deployment Interactions

73

and also precludes duplicate loading of the diverted cargo at a later time. A detailed description of each of the five modules and the interdependencies among them is discussed below.

    a. Aircraft Mobilization (A/C MOB)

    A/C MOB is the single module which comprises the Air Mobilization model. It runs independently of the modules in the Air Deployment model and can be run under numerous and varying assumptions about the availability of the number fo type of aircraft to be used in the operation. The module is independent and its outputs can be stored for use in sensitivity analysis.

    Input to A/C MOB is a file which contains the number of aircraft by type that are available for use during the operation. Associated with each aircraft type is a location distribution and an availability time distribution. The location distribution is based upon the peacetime missions performed by that type aircraft, and the availability times are distributions of unloading the preparation times for that type aircraft.

    The aircraft are mobilized as depicted in Fig. 17. Each aircraft is of type j and is assigned an identification number i, where $i = 1,...,N$ the total number of aircraft. Each aircraft i is examined to determine its type j, and cross referenced to the location distribution
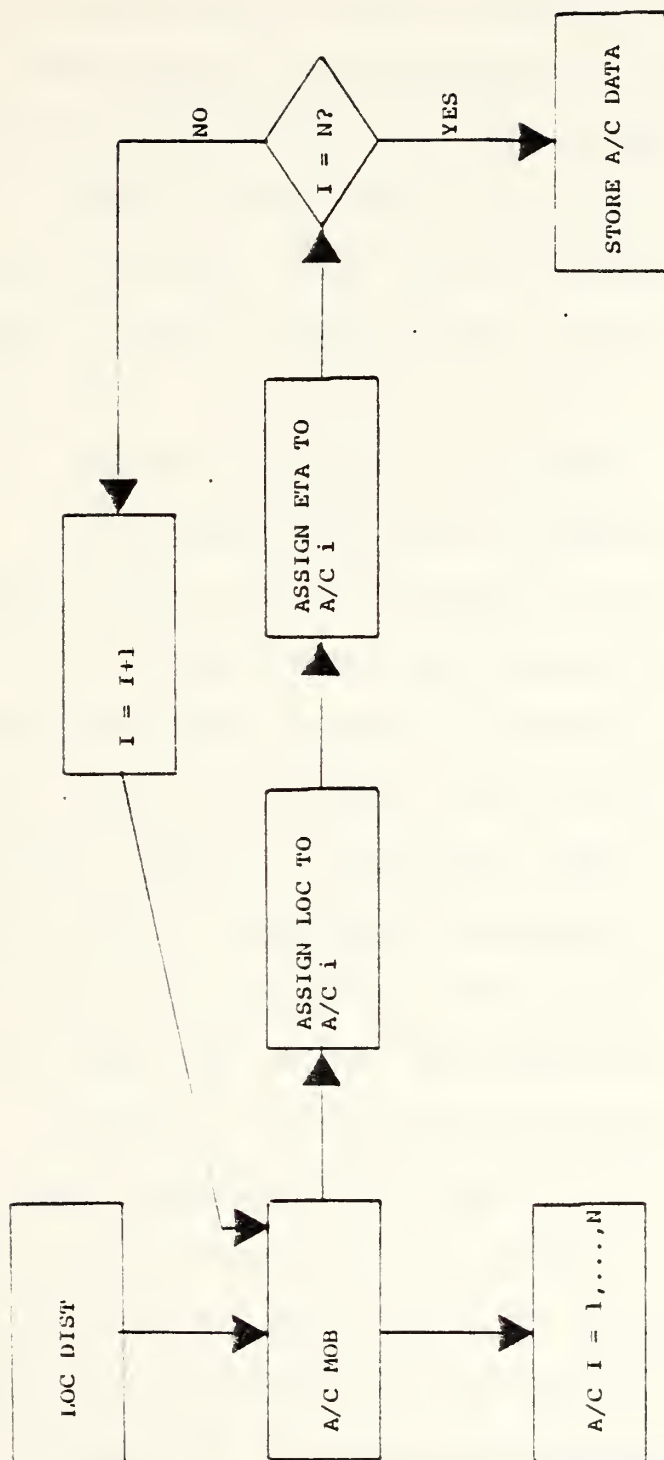
74

Fig. 17. Aircraft Mobilization

75

for type j aircraft. A Monte Carlo simulation assigns a location to the aircraft and the process is repeated using the time distribution j to determine the availability time for the plane at its location. This process is repeated for all N aircraft until each is assigned a location and an availability time. This file is stored and accessed by A/C DTLR to assign missions when the air deployment modules are run.

b. Aircraft Detailer (A/C DTLR)

This module performs the decision making processes which assign initial missions to all aircraft. In addition, A/C DTLR performs any necessary modifications which result from the outcomes of events in the sequencing. Externally, input is received from A/C MOB, S DTLR, and the employment model. In addition, these input requirements within the air deployment modules, A/C DTLR receives and sends files to each of the other modules. Figure 18 depicts the input and output flow associated with A/C DTLR.

Initial input consists of three files, two of which are user generated. The third is the output from the mobilization of aircraft in A/C MOB. The file from A/C MOB lists each of the N aircraft, its type, location, and takeoff time availability from that location. The two input files which are user generated consist of a cargo file containing the type of cargo to be transported, the
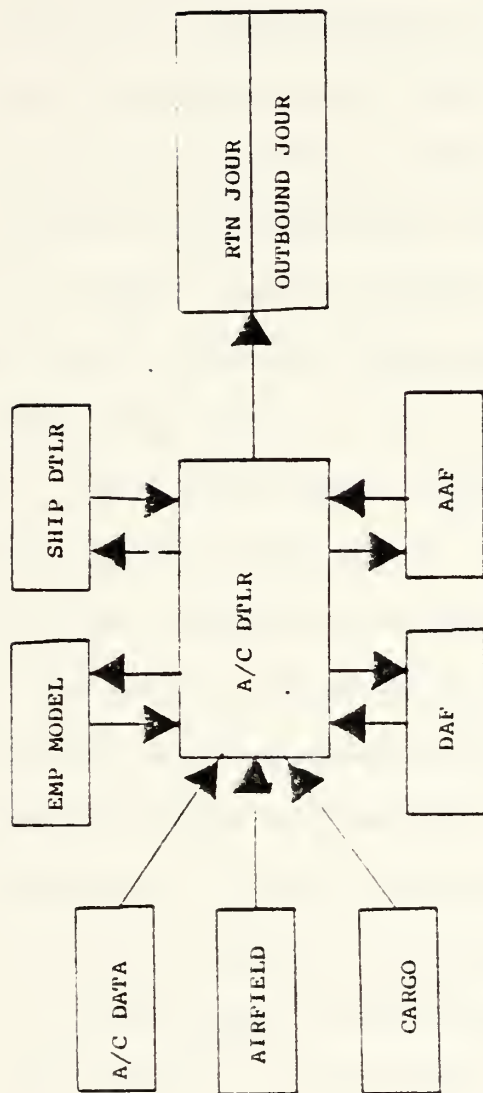
76

Fig. 18. A/C DTLR Input and Output Flow

77

priority of each, and attributes including weight, volume,
time available, and any special handling requirements. An
important characteristic of each cargo type is the priority
assigned to it. The second user input file contains a
listing of airfields in the theater of operation and the
characteristics of each such as runway length and weight or
equipment capabilities. Initial mission assignments to each
aircraft are made by A/C DTLR using this information with
the goal being to best utilize limited resources to effect
the rapid delivery of the most important cargo.

Input from each of the other modules, the em-
ployment model, and S DTLR occur whenever one of the events
which drives the system takes place. This section will
focus on the inputs originating external to the air deploy-
ment modules. Detailed discussion of inputs to A/C DTLR
from modules within air deployment will be deferred until
output from these modules is examined.

Exchange of files with the employment model and
S DTLR serves several important purposes. First, the
exchange with the employment model keeps A/C DTLR appraised
of critical requirements for equipment and troops in the
theater of operations. This allows A/C DTLR to take advan-
tage of aircraft responsiveness to divert planes and rear-
range cargo priorities to meet the need. Explicit in this
rearrangement is the ability to divert cargo from sealift
to airlift by exchanging files with S DTLR. This exchange

78

enables both DTLR modules to reassign missions and loads in
a manner which precludes duplication. The second important
function of the exchange with the employment model provides
information on the tactical situation so that aircraft
scheduled for arrival at fields which are no longer open
can be diverted elsewhere.

The assignment of missions and subsequent ad-
justments is based upon a system of priorities or some type
of objective function. The example in Fig. 19 shows the
processes which take place inside the A/C DTLR module.
The file from A/C MOB is accessed along with the user input
airfield file and time distance calculations performed
which result in the expected flight time for each aircraft
to each of the available airfields. By utilizing the
designated decision criteria, each aircraft is assigned a
mission and an airfield at which it is to pick up its
cargo. The aircraft file which originated in A/C MOB is
modified to include mission assignment, estimated time of
arrival at the airfield, and the priority of its designated
cargo and sent to RTN JOUR, DAF, and AAF. The real world
analogy of this exchange of files from A/C DTLR is the
dissemination of warning orders.

c. Journey (JOUR)

The module journey "flies" each aircraft to its
destination, provides feedback to A/C DTLR on the progress
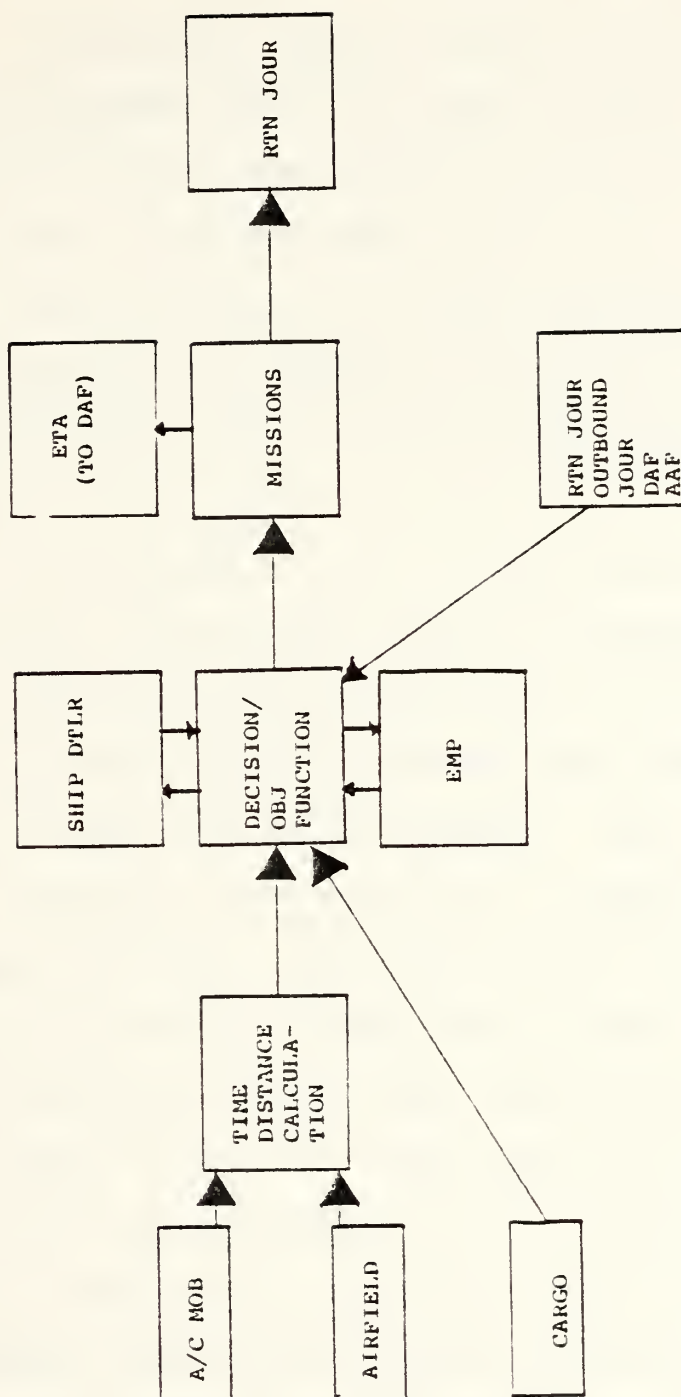of each plane, and implements the instructions from A/C DTLR

79

Fig. 19. Aircraft Detailer Decision Processes

that affect aircraft in the module. For illustrative
purposes, the module has two submodules, RTN JOUR and OUT-
BOUND JOUR. The former returns aircraft to the United States
for mission assignment and the latter directs aircraft
toward destinations in the theater of operations. The
input and output flows are shown in Fig. 20. Because the
input and outputs from each of these submodules are similar
and the processes being modeled are virtually identical,
the discussion will refer to each interchangeably as
appropriate.

As depicted in Fig. 21, the decision processes
in RTN JOUR and OUTBOUND JOUR react to instructions from
A/C DTLR. The most important function of each is to model
the activities and events that affect each aircraft during
the period of time that it is airborne. The file A/C from
A/C DTLR is ready and each aircraft, i, begins its flight
as it becomes available. The module runs until time t, at
which the next aircraft is available to begin its flight or
until the occurrence of some event which affects any of the
aircraft already in the air. Each event distribution is
associated with type aircraft j and its occurrence is
determined by Monte Carlo simulation. If the event occurs,
then the damage distribution function associated with the
event type and aircraft type is assessed and a Monte Carlo
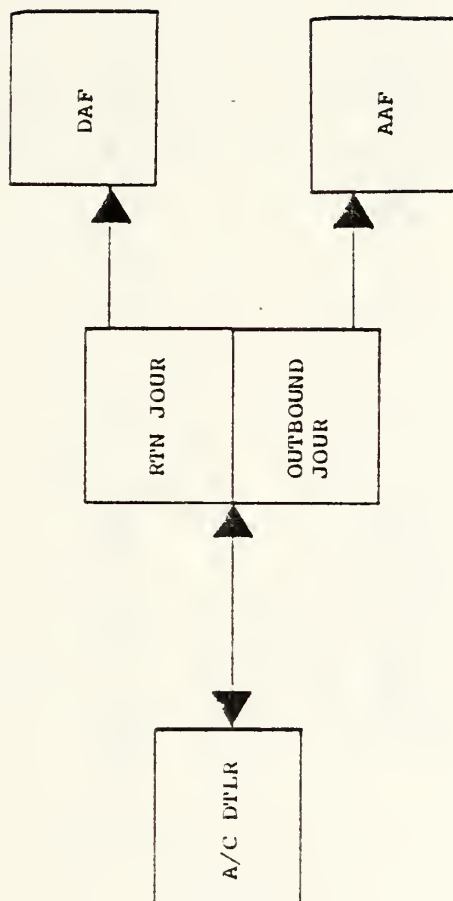roll assesses the damage and any time of delay to affect
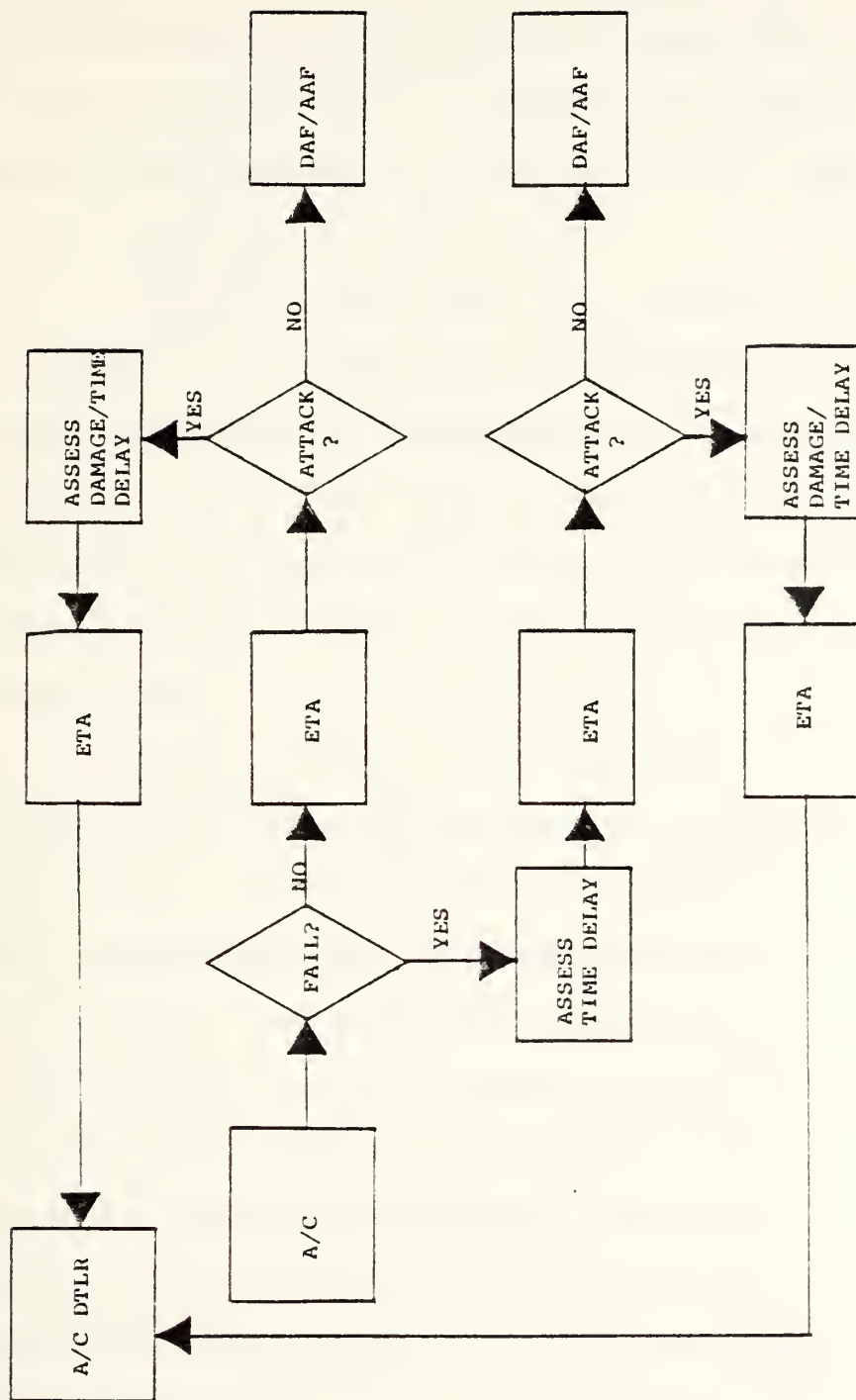
Fig. 20. JOUR Input and Output Flow

82

Fig. 21. JOUR Decision Processes

83

repairs. At the conclusion of each event, its occurrence is sent to A/C DTLR as an information report upon which it acts if appropriate. This process is repetitive and continues until each aircraft has reached its destination or is destroyed and removed from the list of available aircraft.

d. Departure Airfield (DAF)

The module DAF models the activities that take place at a staging airfield which loads troops and equipment on specified aircraft in accordance with instructions from the module A/C DTLR. This module relies upon A/C DTLR for the files which dictate which aircraft and cargoes are to be matched with one another. Figure 22 depicts the flows to and from DAF.

The activities to be simulated at a staging airport include aircraft maintenance and refueling, and the loading of cargo. In this case it is reasonable to use expected values rather than a Monte Carlo simulation for these activities. The mean time between failure and the mean time to repair are good approximations for breakdowns and repairs, respectively. In addition, the mean time to accomplish any required maintenance tasks such as inspection and refueling and the mean time to load each type aircraft are sufficient representations of the time required for all of these planned activities. The projected completion of all of these activities is an output sent to A/C DTLR for
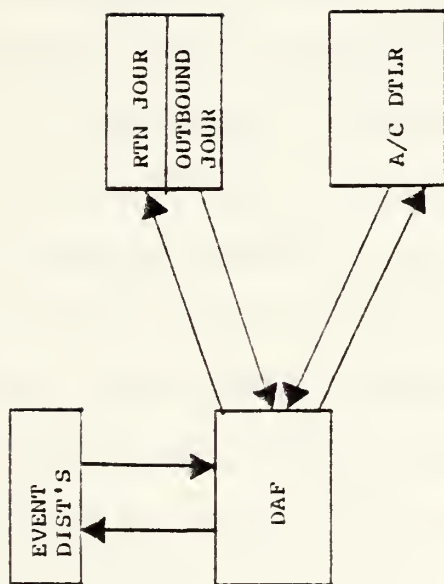
Fig. 22. DAF Input and Output

85

any appropriate scheduling considerations. Figure 23 shows the processes that take place at the departure airfield.

e. Arrival Airfield (AAF)

The modelling processes in AAF are virtually identical in nature to those in DAF except that AAF is subject to enemy interdiction because the airfields lie within the zone of operations. As in DAF this module simulates the activities at a designated airfield and interfaces with the employment model, JOUR, and A/C DTLR. As in DAF, the expected times to accomplish the scheduled tasks at the arrival airport are of sufficient detail to adequately represent the activities which take place. There are two major differences between DAF and AAF. First, the airplanes are unloading cargo in AAF instead of loading. Second, and more importantly, aircraft and facilities at the arrival airfield are in the theater of operations and, therefore, subject to hostile activities. The occurrence and assessment of hostile activity is accomplished through the use of Monte Carlo simulation. Only the aircraft and cargo still on the aircraft are subject to attack. Once cargo is unloaded at AAF, its disposition is determined by the logistics modules and algorithms in the employment model. The interfaces are shown in Fig. 24.

The interface with A/C DTLR serves several important functions. The most important is to provide

86

OUTBOUND JOUR

ALL ACTIVITIES $E[T_{DEPART}] = \Sigma \, E[T_i]$

NO

FAIL?

YES

A/C

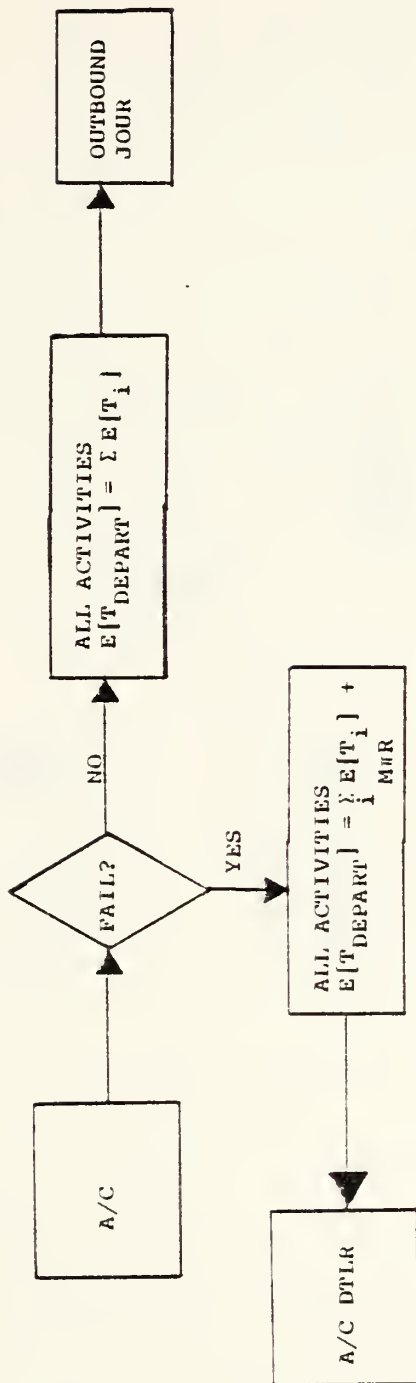ALL ACTIVITIES $E[T_{DEPART}] = \sum_i E[T_i] + M_uR$

A/C DTLR

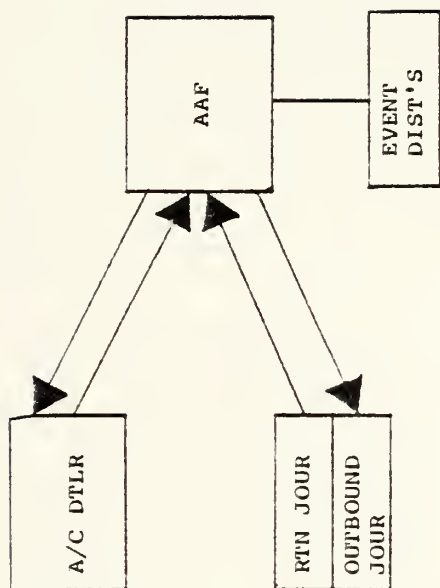Fig. 23. Decision Processes in DAF

Fig. 24. Arrival Airfield Interfaces

assessments of combat with enemy elements while on the
ground and in the process of performing the scheduled
activities of unloading cargo, planned maintenance or re-
fueling. Its other interactions with A/C DTLR are in
essence identical to those of DAF in that they provide the
expected time of completion of activities and takeoff.
Figure 25 shows the decision processes which take place
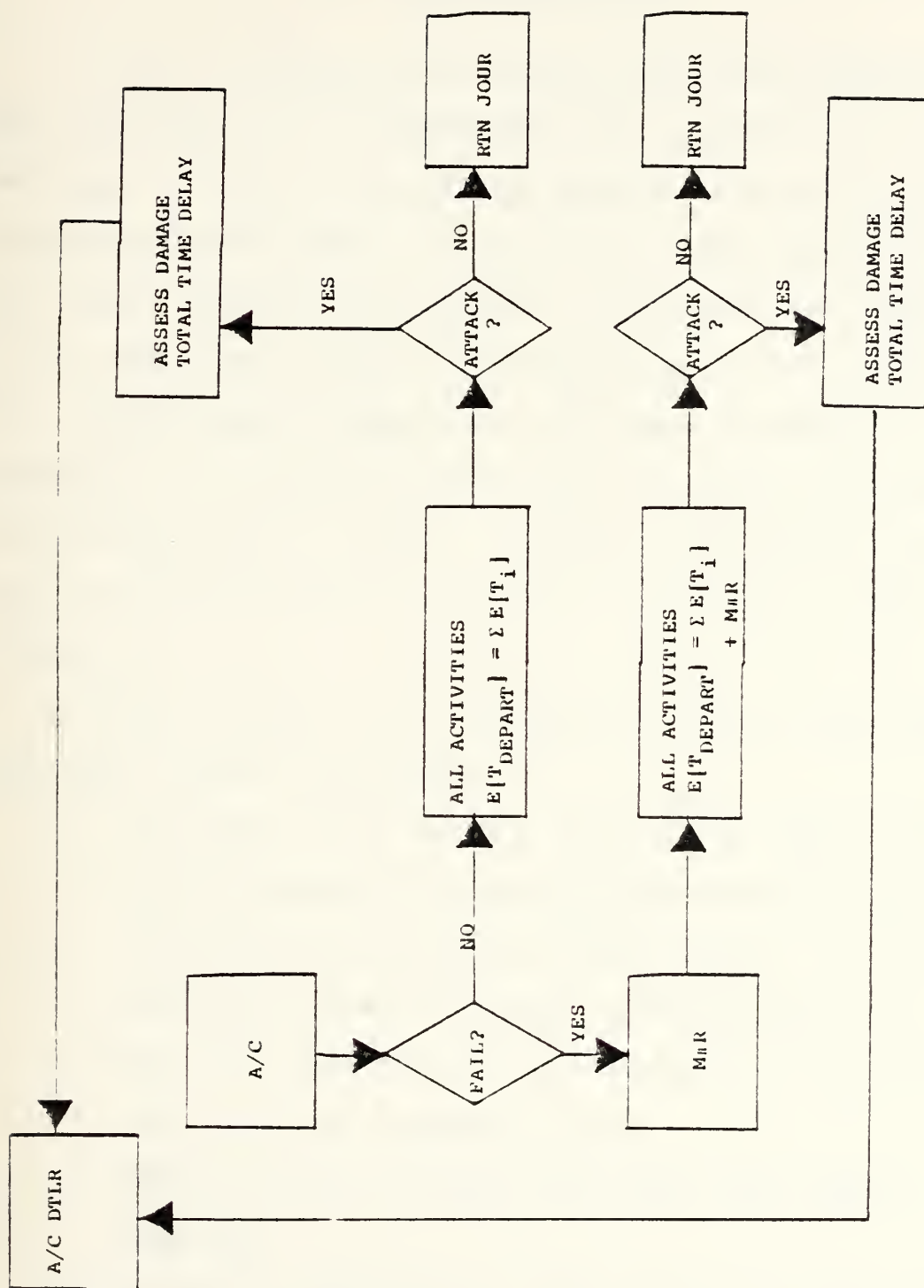in AAF.

Fig. 25. Decision Processes in AAF

IV.   RECOMMENDATIONS

In view of the many contingency plans being prepared
and maintained, it is recommended that a capability be
developed to model the military operations for which con-
tingencies are developed.   This will not only provide a test
for these plans but will generate a data base in support
of the model that can also be used in any crisis planning
that future events necessitate.   In order to develop this
capability, the other possible model structures discussed
in the beginning of Chapter 3 should be explored and compared
with the high resolution simulation structure outlined in
Chapter 3.

If this alternative is selected, there are four areas
that need further development.

1.   The area of the sea and air detailer module needs
     to be explored and a better algorithm developed.

2.   The sea convoy formation module needs to be further
     developed and and a better algorithm designed.

3.   The model then needs to be actually developed and
     translated into computer code.

4.   The data base to support the model then needs to be
     compiled.

The process of developing a better detailer algorithm
can be divided into two parts.   The first area is the

development of a MOE or algorithm that will show a reason-
able relationship between the worth of different items and
their delivery dates. The other area is the actual develop-
ment of an algorithm that will implement the desired
relationship.

There are several possible approaches to the problem of
a viable MOE or algorithm to approach this problem. One
would be to hold the deliveries to a strict priority order.
This would result in a very slow delivery rate because
everything would have to wait for the various items that
were held up for one reason or another. One possible solu-
tion to this would be to allow items to vary in their de-
livery sequence by some set amount. Item 35 must be
delivered no sooner than 15th or later than 55th in the
order of deliveries. This would allow more latitude in
planning. As long as the purpose of this model is to
validate contingency plans, it is important that the model
not be given complete freedom to order deliveries in any
order it sees fit. The ability to do this could be included
for research purposes and this option turned off in produc-
tion runs.

Once the scheme for assigning missions is developed,
the next step is to design an implementing algorithm.
There are several areas that offer promise in this endeavor.
First the actual purpose of the algorithm must be developed

as stated above. Depending on that purpose, there are several possibilities. Logical decision rules like those already developed in the present detailer modules could be one answer. Or perhaps queueing theory or math programming would be more appropriate, depending on the MOE that is chosen.

The convoy formation module suffers from the same problem as the detailer modules. First there needs to be developed a relationship between the delay of a convoy and the risk that convoy incurs. Then risk needs to be related to the enemy situation, convoy size, speed, and escorts available.

Once this relationship has been established, there needs to be an algorithm developed that optimizes the scheduling of convoys based on the relationship. This relationship will probably be intimately tied to the MOE or relationship developed to assign missions and so the detailer module should be developed first.

Once these two problems are resolved, the model needs to be implemented in computer code. To do this the diagrams of the modules provided need to be further developed by steps until they actually specify the code. In doing this more requirements will be found for input/output and functions not outlined may be discovered. Once these outlines are complete, the decision of which, if any, of the present employment models will be used must be made. Then the employment model to be used must be modified to run for

93

the times specified and on the input provided by the mobilization and deployment models. Also, some of the employment model's output will have to be processed to provide the necessary input into the other models.

The last area that requires investigation is the compilation of the various forms of data. This is a labor intensive operation and one that is ongoing. Some of the data required to run this model is very stable; however, much of it changes from year to year and needs to be continuously updated. As the model is enhanced, the requirements for data to support it will grow. Much of the data needed is now available from the interested and affected commands. If this model is eventually to be used as a validation tool, than it is possible that a series of data preprocessors will be necessary to assist the users in maintaining the model's data base.

There will also be various other benefits to developing this model. The developing of the basic relationships between the various inputs and modules will result in a better understanding of the deployment process. Hopefully it will identify chokepoints and problem areas that require more detailed analysis and point out unimportant areas that are now thought to be of major interest.

BIBLIOGRAPHY

Blakeman, W., Bruner, J., and Newman, J., The FOREWON Force Planning System Volume I Basic Report, Research Analysis Corporation, 1969.

Cole, R. H., and Kerlin, E. P., ATLAS: A Tactical, Logistical, and Air Simulation, Research Analysis Corporation, 1969.

Davis, Reed E., Jr., "A Contingency Force Analysis Methodology," ORI Inc., 1982.

General Research Corporation, User's Manual, Rapid Intertheater Deployment Simulation (RAPIDSIM), 1974.

Kefauver, C. J., User's Manual, Unit Movement Simulator (UMS), General Research Corporation, 1972.

O'Brien, Mary J., Posture System Description and User's Manual, General Research Corporation, 1973.

U.S. Air Force, ACOS, Studies and Analysis, Airlift Sorties Required to Deploy Various Army Inits (SABER SIZE), 1 June 1971.

INITIAL DISTRIBUTION LIST

No. Copies

1. Defense Technical Information Center   2
   Cameron Station
   Alexandria, Virginia 22314

2. Library, Code 0142   2
   Naval Postgraduate School
   Monterey, California 93940

3. Department Chairman, Code 55   1
   Department of Operations Research
   Naval Postgraduate School
   Monterey, California 93940

4. Professor J. K. Hartman, Code 55Hh   5
   Department of Operations Research
   Naval Postgraudate School
   Monterey, California 93940

5. Professor S. H. Parry, Code 55 Py   5
   Department of Operations Research
   Naval Postgraduate School
   Monterey, California 93940

6. General Donn A. Starry   1
   Commander
   United States Readiness Command
   McDill AFB, Florida 33608

7. Captain Thomas H. Riddle   1
   814 Edgelawn Street
   Parkersburg, West Virginia 26101

8. Captain Thomas L. Snyder   1
   P.O. Box 321
   Mt. Jackson, Virginia 22842

9. Colonel Christopher Shaw   2
   HQ, United States Readiness Command
   Analysis Support Group
   McDill AFB, Florida 33608

10. Mr. S. W. Hall, Jr.   1
    Joint Deployment Agency
    Deployment Systems Division
    McDill AFB, Florida 33608

96

11. Professor Michael G. Sovereign, Code 55Zo   1
     Department of Operations Research
     Naval Postgraduate School
     Monterey, California 93940